Interdisciplinary Graduate Education Program in Remote Sensing

Involved Departments

Computer Science (CS), Electrical and Computer Engineering (ECE), Forest Resources and Environmental Conservation (FREC), Geography (GEOG), History (HIST), Science and Technology Studies (STS), and Statistics (STATS)

Involved Colleges

Engineering, Science, Natural Resources and Environment, Liberal Arts and Human Sciences

Program Co-Leads

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*Layne T. Watson*, Professor, Department of Computer Science and ICTAS Discovery Analytics Center (DAC), College of Engineering; and Department of Mathematics, College of Science, ltw@vt.edu
Goal

We seek to build on extant strengths to become the only interdisciplinary remote sensing program in the nation that incorporates all aspects of remote sensing, including engineering, theory, data analysis, applications, and policy.

Introduction: Rationale and Need

Remote sensing provides technical and methodological approaches to holistically study human activities that have an impact on the Earth’s sometimes poorly understood physical processes. Remote sensing can be defined as the acquisition of information about an object without making physical contact with it. Sensors use electromagnetic waves in either a “passive” sense using naturally occurring waves (e.g., reflected sunlight) or in an “active” sense using waves generated artificially (e.g., by a radar or lidar system). Because remote sensing systems are often sensitive to wavelengths outside the visible portion of the electromagnetic spectrum (e.g., the infrared and microwave) they allow us to expand our view and "see" the world in a different way. Objective, inter-calibrated, and synoptic data streams from a wide variety of sensors and platforms have become increasingly available since the dawn of the space age. For some systems, archives contain several decades of imagery portraying interactions between humans and the Earth’s environment. While the information resulting from analysis of these data is, by itself, policy relevant, only by combining the information available from remote sensing with the knowledge, approaches, and analytical tools of the social sciences can complex issues at the interface of science and society be addressed. Further, remote sensing itself engenders a variety of social and policy questions, ranging from personal privacy to the social and cultural change that inevitably results from the wide adoption of transforming technology.

Currently, there is no university in the nation that offers an advanced degree in remote sensing that covers the entire spectrum of skills required in the field: from technical know-how and hands-on instrument design experience; to detailed theoretical insight into the underlying physical processes; to cutting edge image processing and data analysis/retrieval skills; to top-level applications of remote sensing data and their policy implications. We are at a critical juncture with faculty expertise and collaborative interests that would enable, through an IGEP, the development of a fully integrated educational experience that would strengthen and enhance the ability of our graduates to address the interdisciplinary challenges facing remote sensing scientists in today’s workplace. Our proposed program at Virginia Tech will meet the existing need by providing a balanced experience for students spanning the domains of engineering, theory, data analysis, applications, and policy.

The proposed graduate program will consolidate and build upon existing remote sensing research and education capabilities which currently reside separately in the Center for Environmental Applications of Remote Sensing (CEARS) formed in 1997 and the Center for Space Science and Engineering Research (CSSER or Space@VT) formed in 2007.
Description

Remote sensing is by its very nature integrative, and, as noted above, Virginia Tech has taken an interdisciplinary approach to remote sensing research and instruction (see figure). Unfortunately, two important gaps (represented by the arrows in the figure) remain, which have kept the (collective) graduate program from going from “very good” to “excellent”. The first is the relative lack of educational integration between the engineering centers (blue) and CEARS (green). The second is the current relative dearth (excepting human geography) of social science (particularly economics and policy) integration that would allow students to use their remote sensing toolkit to tackle complex issues at the interface of science and society. This aspect of our proposed program (“RS Policy” in the above diagram) is a new program element to be led by Richard Hirsch (HIST/STS), Greg Amacher (FREC), and Jay Sullivan (FREC).

Long Term Goals and Intellectual Focus

Our program will train a world-class cadre of interdisciplinary remote sensing scientists to make significant contributions to our understanding of interactions between earth systems and social systems. Our interdisciplinary doctoral program will require 30 hours of coursework. As illustrated below, the possible courses span the Colleges of Natural Resources and Environment, Engineering, and Liberal Arts and Human Sciences, and Science and include courses in remote sensing technologies, computer analysis, natural resource applications and modeling, and statistics. Three courses (7 credit hours total) will be mandatory for all candidates in the program. These include the FOR/GEOG/ECE/CS 5104 Seminar in Remote Sensing, GRAD 5134 Interdisciplinary Research Course\(^1\), and the newly-proposed FOR/STS 5xxx The Science and Policy of Remote Sensing. The inclusion of these three mandatory courses will ensure that all students, regardless of disciplinary background, will be exposed to the same research approach. Further, all students will discuss common scientific and policy issues that have evolved from increasing natural and anthropogenic stresses on the earth system – stresses that are driving research and development in this field. Fifteen additional credits will be drawn from the list of existing and proposed courses shown in Table 1. The remaining credits will be drawn either from Table 1, or from other graduate courses that may be specific to the student’s research interests.

\(^{1}\) Co-taught bi-annually as an interdisciplinary colloquium and research practicum by Drs. Wynne and Scales with involvement of all RS IGEP faculty.
Interdisciplinary Experience and Shared Experiences Requirement

As we set out to design this IGEP we realized we already had two examples of interdisciplinary students of the type envisioned for this program: Jiang Shu (Ph.D., 2009) and Rhonda Phillips (Ph.D., 2009). Shu's work, co-advised by F.A. Kamke of CNRE and L.T. Watson of CoE (co-I of this IGEP proposal), was the development of a computer interface (WBCSim) for wood-based composites modeling and simulation. WBCSim has been used by scientists at Oregon State, Weyerhauser, and other wood products companies. Phillips, co-advised by R. Wynne (co-PI of this IGEP proposal) and Watson, made fundamental contributions to remote sensing and machine learning algorithms.

We learned much from these “prototype” IGEP students. First, interdisciplinary co-advising, while not perfect in all situations, clearly helps students develop depth at the interdisciplinary interface that is not within the purview of either co-major professor. **We thus plan to co-advise across colleges as much as possible within the remote sensing IGEP.** Second, formal multidisciplinary coursework is essential to gain the perspective of other departments/disciplines – thus our common course requirement in Table 1. Third, where feasible, both disciplinary exposure and physical location matters. Drs. Phillips and Shu were both frequently active in the CEARS lab or Brooks Center, respectively, even though they were receiving degrees in Computer Science. **We plan to implement an interdisciplinary experience requirement,** implemented no sooner than completion of the second semester. This requirement will be flexible and tailored to each student, and approved by the student’s committee. It may consist of such activities as time spent in a lab outside the student’s home college, internships, field work experiences, etc. The idea is to enrich the student's perspective and skills through first-hand work in an environment outside his/her prior preparation.

Table 1. Existing Classes

<table>
<thead>
<tr>
<th>Existing Classes</th>
<th>Proposed Classes or Modifications</th>
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<tbody>
<tr>
<td>FOR 5254 Remote Sensing of Natural Resources</td>
<td>FOR/GEOG 6214 Lidar for Env. Sciences</td>
</tr>
<tr>
<td>FOR/GEOG 5104 Seminar on Remote Sensing and GIS</td>
<td>FOR 5XXX RS Aided Mechanistic Models</td>
</tr>
<tr>
<td>FOR 5154 Hyperspectral Remote Sensing of Natural Resources</td>
<td>FOR/ST 5XXX Science and Policy of Remote Sensing</td>
</tr>
<tr>
<td>FOR/GEOG 6214 Forestry Lidar Applications</td>
<td>FOR/CS 5XXX Computing in Environmental Science</td>
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<tr>
<td>GEOG 5374 Advanced Remote Sensing &amp; Phenology</td>
<td>ECE 5XXX Remote Sensing Instrumentation</td>
</tr>
<tr>
<td>STAT 5414 Time Series Analysis (I)</td>
<td>ECE 5XXX Radiative Transfer</td>
</tr>
<tr>
<td>STAT 5544 Spatial Statistics</td>
<td>ECE 5XXX Remote Sensing Theory</td>
</tr>
<tr>
<td>CS 5485 Numerical Analysis and Software (I)</td>
<td>ECE6XXX Passive Remote Sensing</td>
</tr>
<tr>
<td>CS 5486 Numerical Analysis and Software (II)</td>
<td>ECE 6XXX Active Remote Sensing</td>
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<tr>
<td>ECE 5105/5106 Electromagnetic Waves</td>
<td></td>
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<tr>
<td>ECE 5635 Radar Systems Analysis and Design</td>
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<tr>
<td>ECE 5636 Radar Systems Analysis and Design</td>
<td></td>
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<tr>
<td>ECE 6104 Advanced Topics in Electromagnetics</td>
<td></td>
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<tr>
<td>ECE 6106 Random Surface Scattering</td>
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</table>

Interdisciplinary Experience and Shared Experiences Requirement

As we set out to design this IGEP we realized we already had two examples of interdisciplinary students of the type envisioned for this program: Jiang Shu (Ph.D., 2009) and Rhonda Phillips (Ph.D., 2009). Shu's work, co-advised by F.A. Kamke of CNRE and L.T. Watson of CoE (co-I of this IGEP proposal), was the development of a computer interface (WBCSim) for wood-based composites modeling and simulation. WBCSim has been used by scientists at Oregon State, Weyerhauser, and other wood products companies. Phillips, co-advised by R. Wynne (co-PI of this IGEP proposal) and Watson, made fundamental contributions to remote sensing and machine learning algorithms.

We learned much from these “prototype” IGEP students. First, interdisciplinary co-advising, while not perfect in all situations, clearly helps students develop depth at the interdisciplinary interface that is not within the purview of either co-major professor. **We thus plan to co-advise across colleges as much as possible within the remote sensing IGEP.** Second, formal multidisciplinary coursework is essential to gain the perspective of other departments/disciplines – thus our common course requirement in Table 1. Third, where feasible, both disciplinary exposure and physical location matters. Drs. Phillips and Shu were both frequently active in the CEARS lab or Brooks Center, respectively, even though they were receiving degrees in Computer Science. **We plan to implement an interdisciplinary experience requirement,** implemented no sooner than completion of the second semester. This requirement will be flexible and tailored to each student, and approved by the student’s committee. It may consist of such activities as time spent in a lab outside the student’s home college, internships, field work experiences, etc. The idea is to enrich the student's perspective and skills through first-hand work in an environment outside his/her prior preparation.
Finally, our “prototypical” IGEP students did not benefit from one other experience that we consider crucial to the success of this or any other IGEP, namely group cohesion. Absent shared physical space – which would be ideal – cohesion is best achieved through shared experiences. Shared experiences will include group meetings (bi-weekly, akin to the current CEARS meetings), shared spring seminar attendance (expanded version of FOR/GEOG 5104, which was cross-listed in CoE until very recently), and shared required courses.

Student Recruitment and Retention

Students will be recruited as part of the graduate programs in each participating department, and will be selected according to a multi-college committee representing the affiliated faculty. In addition, we will advertise through a dedicated program web page and through appropriate professional societies. The fellowships provided by the IGEP will be used as recruitment tools for strong candidates. Our affiliated faculty has a strong history of collaboration and research funding (Appendix B). We anticipate that any student on an IGEP fellowship will be transferred to research funding after 1 year. IGEP doctoral students will also be encouraged to compete for pertinent doctoral fellowships offered by NASA, NSF, EPA, etc. We anticipate that student demand for the program will exceed capacity and have set a long-term enrollment goal of 20-22 doctoral students; we plan to admit at least five students annually.

Assessment

Our assessment of the IGEP program will be focused in two areas: (1) the measurement of performance outcomes of students while in the program, and (2) the success of the PhD program as a whole. Several measures will be applied to determine the success of the proposed Ph.D. program. These include measures of student quality, student enrollment, graduation rates, student satisfaction, presentations at national/international conferences, peer-reviewed joint publications and their citation rates, employment of graduates, employer satisfaction, and, longer term, success of graduates of the program. We will report annually to our stakeholders committee (constituted according to University Centers Policy but including external stakeholders) to ensure program relevance and quality. Further details of our assessment plan are shown in Appendix B.

Conclusion

This IGEP will fulfill a critical current need for Virginia and the nation by creating a unique interdisciplinary program. The time is ripe for such a program: never has there been more need from both a scientific and societal perspective for scientists fully trained to fully exploit the terabytes of information daily available from air- and spaceborne sensors. Ever-increasing natural and anthropogenic influences on the earth system necessitate the formation of a cadre of scientists well-trained in this integrative discipline. Virginia Tech has the resources needed to lead in this field – what has been lacking is the will to integrate our historical pillars of strength into a truly interdisciplinary academic program encompassing engineering and the natural and social sciences.
Appendix A: Program Sustainability and Program Assessment

Program Sustainability: Plans for Securing External Funding

The investigators involved with this proposal are well-funded engineers, social scientists, and natural scientists with a long history of collaboration within extant interdisciplinary groups. While collaborative funding across groups (e.g., between CEARS and CSSER faculty) has not yet occurred, we do not see this as a barrier to the successful implementation of this IGEP. We are already examining areas in which proposal teams can sensibly be constituted across this divide, and, more importantly, have identified areas in which collaboration is important to improve student projects. As a case in point, Jo Baker (ECE) recently worked with Randy Wynne and his student Alicia Peduzzi to better understand the interactions of multiband InSAR data with forest canopies. In the end, we are committed to working with each other to (1) ensure a sustainable extramural funding stream and (2) enhance the quality and interdisciplinary nature of remote sensing graduate education at Virginia Tech. Furthermore, the long-term sustainability of the program is guaranteed because of the high priority placed on remote sensing capabilities by the Federal government, with both research and high-level specialist training supported by NSF, EPA, NASA, NOAA, and DoD. Commercial remote sensing firms also take a keen interest in the development of skilled personnel, as evidenced by current collaborative remote sensing research programs that focus on student support with companies such as Science Applications International Corporation (SAIC).

Program Assessment

Measuring PhD Fellow Performance Outcomes

Participating departments have methods for evaluating graduate student progress that will be followed for each Fellow. Each graduate student will be evaluated annually by their advising committee, the department head, and the college graduate coordinator(s). This advising committee will be guided by clear performance milestones corresponding to existing departmental guidelines. Activities throughout each Fellow’s training will ensure the development of professional core competencies in the relevant research area. These include submission of peer-reviewed manuscripts, participation and presentation at national and international professional meetings, participation in professional internships with resource management organizations, and teaching experiences.

Each student will have, at a minimum, an annual meeting with the committee where a written report of student progress is provided by the committee. This report includes an evaluation of coursework, research progress, presentations, publications, and teaching experience. The IGEP Fellows will complete all required coursework and a research working plan by the beginning of the 4th academic semester. Once the working plan is approved, the Fellows will complete a written and oral candidacy exam focusing on the general area of their research. This candidacy exam will be completed by the end of their 4th academic semester, at least six months prior to the final defense. The periodic evaluations of the Fellows will be used to compare their accomplishments and progress to that of other departmental graduate
students. The interdisciplinary committees for the Fellows will ensure adherence to these evaluation milestones and mentor the Fellows to timely completion of their degrees. We will aim for 100% completion rates with the Fellows and will evaluate the completion success with regards to the average completion times of the institution and the respective colleges over the past 2 years.

An exit interview will be given to all graduates and this will allow us to collect contact and career information initially and facilitate contact between the graduated Fellows and the committee members. Our program goal is to maintain contact with the IGEP graduates for 5 years after they complete their Fellowship. Collected information will provide the foundation for a formal tracking system for graduates as the program grows. In addition, the Fellows’ trajectories will be analyzed to determine which of the support services and additional programs (mentioned above) proved most helpful to the future success of the Fellows. This will inform our mentorship for future students/Fellows.

**Self-Assessment to Evaluate the Success of the PhD Program as a Whole**

Annual self-assessment will be completed within the team of Project Directors who will meet at the completion of the Fellowship program to self-critique and provide suggestions for how to improve our activities as educators of the next generation of remote sensing scientists. Until the first cohort of students completes the program, the assessment will focus on measures of student quality, student enrollment, student satisfaction, effectiveness of the interdisciplinary experience program, effectiveness of the mandatory cross-college classes, and cross-college collaborations.

Measures of student quality include: (1) performance in courses; (2) annual evaluations; (3) performance in internships; (4) achievement of milestones; (5) participation in conferences and publication efforts (and citation rates); and, (6) participation in proposal/grant efforts. Enrollment metrics include (1) number of applicants and accepted candidates; (2) quality of applicants (GPA, prior publications, prior research experience, etc.); (3) breadth of applicants and accepted candidates across disciplines; and (4) internal versus external applicants.

The interdisciplinary experience requirement will be individually tailored to each student, and as such, the metrics used to evaluate its success will vary. At a minimum, we are looking to see that the experience is cross-disciplinary and fosters research and learning outside what is traditionally available in the student’s home department.

Tailored course evaluations, which include additional questions about the interdisciplinary make-up of the class and its relevance, will be used to assess the mandatory cross-college courses. Surveys and interviews will be used to assess student satisfaction with the program. After the first cohort of students graduate, we will also track the employment of our graduates and employer satisfaction.
November 10, 2011

TO: IGEF Evaluation Committee

FROM: Paul M. Winistorfer, Dean, College of Natural Resources and Environment

SUBJECT: Interdisciplinary Graduate Education Program in Remote Sensing

To whom it may concern:

The College of Natural Resources and Environment fully supports the proposed multidisciplinary IGEF Proposal in "Interdisciplinary Graduate Education Program in Remote Sensing."

No additional college resources are required for the IGEF proposal.

This proposal has been developed by a group of faculty representing 4 colleges and 6 academic departments. Remote sensing is an emerging area of strength on the campus, as evidenced by the cooperation on this proposal. We have particular strength in remote sensing in the College of Natural Resources and Environment.

Securing IGEF support would elevate the campus profile and bring strategic resources to the effort. CNRE is fully in support of this effort.

November 9, 2011

Dr. Karen DePauw
Vice President and Dean of the Graduate School

Dear Dr. DePauw:

I am pleased to strongly endorse the proposal for an Interdisciplinary Graduate Education Program (IGEP) in Remote Sensing submitted by Professors Randolph Wynne and Wayne Scales, et al. In my opinion this is a well laid out and compelling proposal that has potential to greatly strengthen graduate educational efforts in a spectrum of Colleges across the University. The faculty members involved are leaders in both educational and research aspects of remote sensing which is a field of great interest to the University. The College of Engineering has made substantial investments over the past decade in programs which utilize remote sensing science and technology. These include world class academic units in wireless telecommunications, space science and engineering, national security, and various aspects of computational science. All of these programs involve diverse interdisciplinary research agendas which have seen a substantial uplift in graduate student enrollment. Development of cross-disciplinary graduate curricula associated with the IGEF will be well received with this recent graduate student population growth and is expected to contribute to continued growth. It is exciting to see the possibilities for our engineering faculty members to collaborate with faculty members outside of engineering to develop this interdisciplinary curriculum. It will clearly benefit a diverse spectrum of graduate students and greatly strengthen our own graduate programs. I strongly support this proposal and am highly optimistic about its success and impact on the graduate programs of all the engineering departments involved.

Sincerely,

Richard Benson
Dean of Engineering
Torgersen Chair
November 10, 2011

Dr. Karen DePauw
Vice President and Dean of the Graduate School

Dear Dean DePauw:

This letter is to endorse with great enthusiasm the proposal for an Interdisciplinary Graduate Education Program in Remote Sensing, submitted by Drs. Randy Wyne (IFRE), Wayne Seales (ECE) and ten core faculty members.

We are living in a world saturated with information, and automatic collection of huge amounts of raw data coming from ubiquitous remote sensors is changing our everyday lives, sometimes in ways neither properly understood nor beneficial to people. To make matters worse, there are not enough human resources to fully analyze the data, uncover the natural and human phenomena, and utilize the rich information for better understanding of the nature around us and ourselves. The scientific implications of the remote sensing data cannot be overemphasized.

We understand that currently there is no advanced program in remote sensing that covers the entire spectrum of skills in the field, and this IGEP program at Virginia Tech will meet this need by providing a balanced experience for students in natural and human sciences, and engineering. We understand that Layne Watson (MATH/CSE) and Dong-Yun Kim (STAT) are actively involved in the proposal. Dr. Watson is a charter member of Wyne's Center for Environmental Applications of Remote Sensing (CERS), and Dr. Kim has been collaborating with team members on climate and land usage changes based on remote sensing data. We are confident that they will make meaningful contributions to advance the field of remote sensing, and their interdisciplinary collaborations will greatly enhance the IGEP program. We strongly support the proposal for IGEP in Remote Sensing.

Sincerely,

Nancy Rola
Associate Dean, COS

Peter E. Haskell, Head, Mathematics
Eric P. Smith, Head, Statistics

Mark V. Barrow, Jr.
Professor and Chair
Dear Dr. DePauw,

I am writing this letter to express the department of Geography’s support for the IGEP Proposal, “Remote Sensing.” This uniquely broad view of a major geographical technology is long overdue. In our discipline, we have spent many years teaching students the skills inherent in applying remote sensing in the field. But, we have not had a structure that supports students to develop an understanding of the full depth and breadth of the social impacts of these technologies, nor, most importantly, the interdisciplinary environment that nurtures this goal. Therefore, this IGEP proposal is easy for our department to endorse because it adds these two dimensions that are currently lacking in our graduate program.

I foresee a great deal of interest in this area as it will produce graduates possessing the knowledge to be the next generation of leaders in the field. From designing and developing satellite sensors—currently an engineering topic—to applying these sensors to environmental and human problems—currently a Forest Resources and Environmental Conservation and Geography topic—to the social effects of data gathering and policy emanating from these data—currently not addressed in a cohesive manner at Virginia Tech, this program is extremely exciting. Further, it is entirely within the spirit of IGEP.

While none of us can do it alone, the connections made by this program are clearly desirable and significant. With this program, Virginia Tech will gain the recognition it deserves in this area.

Sincerely,

Laurence W. Carothers Jr.
Professor and Head

Virginia Tech
College of Natural Resources and Environment

November 9, 2011

Dr. Karen P. DePauw
Vice President and Dean for Graduate Education
Graduate Life Center at Donaldson Brown (G505)
Virginia Tech
Blacksburg, Virginia 24061

Dear Dean DePauw,

I am pleased to strongly endorse the proposal for an interdisciplinary Graduate Education Program (IGEP) in Remote Sensing submitted by Professors Randolph Wynn and Wayne Scales and their collaborators. Remote sensing is a rapidly changing field with constant new developments in high-resolution multispectral sensor technologies; advanced data analysis and processing techniques; and ever expanding commercial, scientific and environmental applications. Meeting the graduate educational needs and leveraging the research opportunities in remote sensing requires a collaborative, interdisciplinary approach. The unique aspect of the proposed program is its emphasis on providing graduate students a balanced exposure to the full spectrum of remote sensing activities spanning engineering, theory, data analysis, and applications. This program will utilize existing strengths at Virginia Tech and is an appropriate culmination of ongoing inter-departmental collaborations involving multiple ECE faculty members. Within the ECE Department, remote sensing is currently a core research component of the space science and wireless telecommunications programs, which have rapidly grown to national and international prominence in recent years. There are also significant synergies with the new Institute for National Security and Technology, which involves a number of ECE faculty members. I am strongly supportive of this proposal and particularly enthusiastic about the proposed new course development, joint taught courses, and cross-listed courses that will provide ECE graduate students a broad exposure to remote sensing applications and data analysis techniques. I greatly appreciate your various consideration and approval of this proposal for support.

Yours truly,

Scott F. Mallick
Professor and Department Head

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November 8, 2011

Dr. Karen P. DePauw
Vice President and Dean for Graduate Education
Graduate Life Center at Donaldson Brown (G505)
Virginia Tech
Blacksburg, Virginia 24061

Dear Dr. DePauw,

I endorse the proposal IGEP in Remote Sensing submitted by Drs. Wynn and Scales and additional faculty members from six departments and four colleges. The goal of the proposal is to build on extant strengths to become the best interdisciplinary remote sensing program in the nation. We will draw resources from a world-class cadre of interdisciplinary remote sensing scientists who will make significant contributions to our understanding of the earth system. In addition to the research and education requirements common to all Ph.D. students at Virginia Tech, this interdisciplinary doctoral program will have 30 hours of required coursework.

The IGEP will fulfill a critical current need in Virginia and the nation. It will create a program unique nationally and internationally by both size and interdisciplinary scope. The time is right for such a program. Never has there been more need from both scientific and societal perspectives for scientists trained to help explain the explosion of information daily available from air- and space-borne sensors.

I believe that this program will be successful due to active participation and collaboration of faculty across campus.

Sincerely,

Jonas R. B. Almskog
Professor and Department Head