NEW PARADIGM, NEW APPROACHES: RESTRUCTURING GEOSPATIAL INFORMATION EDUCATION AND TRAINING IN A TRADITIONAL RESEARCH UNIVERSITY SETTING

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ABSTRACT

The basic context within which education and training in photogrammetry, remote sensing, and GIS reside has changed dramatically over the last several years. Once considered rather separate areas of study, these three fields today enjoy an increasing degree of conceptual and technological symbiosis. At the same time, these once "exotic" technologies have become absolutely central to the conduct of science, government, and business alike. As global society continues its transition from geospatial information literacy to geospatial information dependency, tremendous challenges and opportunities present themselves to institutions of higher learning in providing adequate education and training in this new paradigm. Traditional disciplinary courses, curricula, and research programs will not meet the needs of the future.

This paper highlights the rationale for, and substance of, several interrelated changes that have been made in the educational and training offerings of the Institute for Environmental Studies at the University of Wisconsin-Madison. Among these changes has been: 1) offering introductory geospatial information courses in a 5-week, modular format, as opposed to a 15-week, semester-long format; 2) creating a "professional," non-thesis masters degree option in Remote Sensing and Spatial Information Management to complement our traditional research-based degree option; 3) implementing an applied, commercially-focused thrust to complement our historically "academic" research and development program; and, 4) participating in an inter-institutional university consortium aimed at extending EOS-era remote sensing technologies to the solution of problems of regional geographic scale and significance. In short, the new geospatial information paradigm has led us to make multifaceted changes in everything from our courses, curricula, research program, and technology transfer activities to changes in administrative and financial arrangements. We believe such holistic restructuring is key to meeting the challenges and reaping the opportunities of the next era of geospatial information education and training.

1 INTRODUCTION

1.1 The New Paradigm

The basic context within which education and training in photogrammetry, remote sensing, and GIS reside has changed dramatically over the last several years. Once considered rather separate areas of study, these three fields today enjoy an increasing degree of conceptual and technological symbiosis. In fact, the lines between these areas of study have become quite blurred and today's student often seek "end-to-end" training in everything from image processing of high resolution satellite data to softcopy photogrammetry, GPS operation, spatial reference systems, and customization of GIS operations for various forms of spatial modeling and analysis. At the same time, the demand for such instruction is not simply focused in a single disciplinary major, but rather it spans a broad range of the physical, biological, and social sciences. All this is happening as major segments of global society are evolving from a stage of geospatial information literary to geospatial information dependency in the conduct of science, government, and business alike.

Hence, the driving force for the new geospatial information education paradigm is not simply the "push" of ever-improving spatial technologies, but also the "pull" of such varied local to global issues as land use planning, water resource management, precision agriculture, world population, environmental quality, sustainable development, and global change. At the same time, we are witnessing continued institutional change and the associated redefinition of the respective missions and roles of the educational, governmental, and commercial sectors of our modern society.

1.2 Re-Thinking the Design of Selected Geospatial Information Education and Research Programs at the University of Wisconsin-Madison

It is in the above context that we have begun to re-think the design of certain aspects of our geospatial information educational and research programs. The University of Wisconsin-Madison (UW) is a public, land-grant institution founded in 1849. It has over 130 academic departments and offers a full range of disciplinary specialties to approximately 28,000 undergraduates, 8,800 graduate students, and 1,900 students in professional programs. It also has one of the largest and most diverse research programs in the US, with more than $370 million in revenue and over 9000 active projects at any given time. UW also enjoys a rich heritage in “outreach” and partnership with the citizens, communities, agencies, and industries of the state. This model of partnership has been dubbed by many as “The Wisconsin Idea”, and dates to 1866 when the university first received its land-grant designation.

Geospatial information instruction and research programs are incorporated in many departments and schools and colleges at UW (e.g., civil and environmental engineering, forest ecology and management, geography, urban and regional planning landscape architecture, and soil science). This paper focuses on recent changes made by a specific subset of these programs; namely, the Department of Civil and Environmental engineering (CEE) and the Institute for Environmental Studies (IES). As outlined below, these programmatic changes include: 1) offering introductory courses in a modular format, 2) creating a “professional” non-thesis masters degree option, 3) implementing an applied, commercially-oriented remote sensing research program, and 4) participating in an inter-institutional consortium focused on the use of EOS-era remote sensing tools to assist in the identification and solution of problems of regional geographic scale and significance.

2 DEVELOPMENT OF MODULAR COURSES FOR INTRODUCTORY PHOTOGRAMMETRY, REMOTE SENSING, AND GIS/LIS INSTRUCTION

2.1 Rationale

One of the most sweeping changes we have made in introductory photogrammetry and remote sensing courses is the repackaging of traditional semester-long courses into a series of shorter, modular offerings. Our traditional course offerings were typically three-credit courses that met three times per week (for 50 minutes), for a 15-week long semester. Each modular course is offered for one credit and typically meets three times per week (for 50 minutes), but for only a 5-week period. (Modules involving a laboratory typically meet twice per week for lectures, and for one two-hour laboratory).

Conversion of our introductory courses into a modular format was undertaken from a number of perspectives. From the point of view of the student, one-credit modules offer flexibility in fitting such courses into already heavy course loads. Students can elect to carry as few, or as many, of the modules as their interests and schedules permit. They can also tailor their selection of modules to best meet their individual needs. Also, because the modules are very tightly focused, there is virtually no redundancy among them, as these often is with semester-long courses. (For example, a student taking both a traditional photogrammetry and a remote sensing course would likely be exposed to material treating aerial film cameras and digital cameras in both courses). While some repetition of material is desirable, students were reporting that there was too much of same in many of our traditional offerings.

From the instructor’s or department’s point of view, the minimization of redundancy among courses results in the most efficient use of limited instructional resources. As with student schedules, an instructor’s teaching load is somewhat more flexible in that teaching effort is organized according to five-week, rather than 15-week, blocks of time. Through proper planning, certain five-week periods can be designed to minimize the conflict between teaching and such activities as professional travel, research, writing, or new course development.

2.2 Courses

We initiated the modular course approach in the Spring 1993 Semester with the creation of the 14 one-credit modules listed below. All of these courses are either offered by IES or CEE. Many of the offerings are cross-listed among IES, CEE, Forest Ecology and Management, and Geological Engineering. Several modules can be taken in sequence during one semester, including the sequences 301-302-303, 301-403-404, and 301-403-304. As scheduling permits, it is also possible to take more than three modules in a semester. Also, students may continue study beyond the modules by taking any of the numerous intermediate and advanced semester-long courses offered on our campus.

301 – Introduction to Aerial Photographic Systems. (Lecture only).
302 – Introduction to Electro-optical and Microwave Remote Sensing Systems. (Lecture only).
303 – Introduction to Remote Sensing Digital Image Processing. (Lecture and lab).
304 – Remote Sensing Visual Image Interpretation and GIS Integration. (Lecture and lab).
305 – Photographic Processing. (Lecture and lab).
307 – Fundamental Computations for Land Information Systems. (Lecture only).
308 – Spatial Frameworks for Land Information Systems. (Lecture only).
309 – Introduction to U.S. Public Land System. (Lecture only).
403 – Geometric Analysis of Vertical Aerial Photographs. (Lecture only).
404 – Mapping with Aerial Photographs. (Lecture and lab).
405 – Digital Photogrammetry. (Lecture and lab).
406 – Remote Sensing Instrumentation. (Lecture and lab).
407 – Adjustments for Land Information and Surveying. (Lecture only).
408 – Adjustments for Surveying and Geodesy

2.3 Experience to Date with the Modular Approach

As one might assume, the modular approach has proven to have both advantages and disadvantages. Among the principal advantages has been the aforementioned efficiency of course offerings. The 14 initial course modules "replaced" 21 credits of existing courses (some three-credit courses have become one-credit modules). Students enjoy the flexibility in course selection and multiple-course tailoring to meet their needs. Similarly, the modular approach provides greater flexibility and efficiency in course requirements and recommendations by department and graduate programs. (Some 65 students take the first modular course, 301, every semester).

The modular courses also permit students transferring from other institutions into the UW to fill in potentially missing background knowledge with a minimum of redundancy of material they may already have studied elsewhere. Also, non-traditional students, such as working professionals, find it less disruptive to their schedules to take courses in five-week blocks of time.

The modular approach has also proven to provide greater flexibility in teaching activities by faculty. "Teaching loads" can be better balanced in this manner, and faculty can tend to focus their teaching in areas of their greatest expertise. Another major advantage is the ability to more easily develop new courses (and delete old courses) in the modular format. For example, since the original modules (above) were developed, we have stopped offering such courses as "Photographic Processing," and have initiated such modules as "Differential GPS." One can envision counterpart offerings in such rapidly changing areas as "Feature Extraction from High Resolution Imagery," "Hyperspectral Data Analysis," or "Interferometric Radar Data Analysis."

The principal disadvantages to the modular courses revolve around the foreshortened duration of this format. Student absence from class, even if brief, is hard to recover from. Course grades are based on fewer tests, homework sets and written reports than in a typical semester-long course. Counterbalancing these effect is the fact that each module is only one credit, so student performance in a sequence of such courses should average out to be similar to that achieved in traditional course offerings.

In general, we have found the advantages of the modular approach to far outweigh the disadvantages. They have proven to increase the access, popularity, efficiency, diversity and currency of our offerings.

3 CREATING A "PROFESSIONAL" MASTERS DEGREE OPTION IN REMOTE SENSING AND SPATIAL INFORMATION MANAGEMENT

3.1 Rationale

In addition to making the aforementioned changes in our various courses, we have also expanded our Environmental Monitoring graduate program to include an M.S. option in "Remote Sensing and Spatial Information Management." This new option is a non-thesis track in the program that parallels our traditional, thesis-based option in "Remote Sensing and Spatial Information Science and Technology." The new "professional" option has been designed to meet the rapidly growing demand for scientifically and technologically fluent professionals who are able to manage geospatial multidisciplinary projects and programs.

The Alfred P. Sloan Foundation is supporting the development of new Science Masters degree programs around the nation (Jensen, 1999). These professional graduate programs provide pathways for students to retool and gain new expertise in cutting-edge science and information technology applications. The students systematically increase their proficiencies and responsibilities in managing projects within an area of scientific application.

The Environmental Monitoring Professional Masters degree at the University of Wisconsin has attracted both mid-career and recent graduate students. The mid-career students often arrive with management experience and seek to add new geospatial information analysis and application tools to their repertoire. Recent graduates apply with strong science backgrounds, but often lack marketable skills for employment. These two groups of students find common ground in learning to apply aerial and satellite remote sensing, photogrammetry, digital image interpretation, GPS and GIS for research, analysis and decision-making. They also learn from one another as they bring complementary skills and knowledge to shared academic and career goals.

During the first year of the program, emerging trends suggest that most mid-career students will take many of their classes part-time while continuing to work. Recent graduates tend to minimize their economic opportunity costs by enrolling full-time and seeking university project assistantships that resonate with their career goals; such as those funded by our NASA-sponsored remote sensing commercialization program (see Section IV).

3.2 Curriculum Description

The professional non-thesis Masters degree option (shown below) has been designed for graduates to be very productive with minimal training when they are first employed as: geospatial project team members, managers and/or consultants in the private, governmental or non-profit sectors. As such, the curriculum progresses from a sound foundation in the science of geospatial information systems (GsIS) technology through to the ‘business’ of designing project goals, carrying out needs analyses, planning tasks, identifying metrics for assessment and evaluation, budgeting for software and hardware needs, communicating effectively, organizing team participation, meeting benchmarks and deadlines, and in providing high quality products. Curriculum goals and activities are focused on how the successful students can perform as managers in a rapidly evolving geospatial context when they enter or re-enter the world of work.

Topic	Courses	Credits
Introduction to Remote Sensing	301-302-303	3
Introduction to GIS	377 or 655, 308	4
Introduction to Differential GPS	659	1
Digital Image Interpretation or Algorithm Development	556 or 758	3
Advanced GIS Applications	579 or 656 or 695 or 900	3
Technical Depth Electives	Choice of 35 Courses	6
Environmental Monitoring Seminar	Enrollment Each Semester	1-4
Seminar in Application Field	Any Application Seminar	1
GIS Implementation: Organizational, Legal and Ethical	New Course	3
Capstone Experience	Practicum 765, 766; Internship; or Independent Study 999	3-6

Several observations drive this formative curriculum design. First, many of the Environmental Monitoring students have been drawn into employment before they finish their degrees by the economic value of their technical prowess. At the same time, employers often voice a need for more organizational and management skills in new technically strong employees. Former Environmental Monitoring students have also been quickly moved into positions with more management responsibilities during their first year of work. Finally, we see ourselves preparing professional M.S. program students for work in the more applications-oriented of two areas of rapid growth; multidisciplinary GsIS project management as opposed to research and development based in the computational foundations of GsIS.

To bridge from academic to employment contexts, all Professional M.S. degree students can choose from one of three capstone experiences that capitalize on their background, limitations and aspirations; a two semester project practicum in which geospatial information is central (larger group with more specialized team member roles), a mentored internship (recent graduates), or a supervised independent study project (for students with extensive professional experience). Each of these require students to write a project plan, select a supervisor or mentor, carry out a project, and write a report.

3.3 Program Success and Continuing Evolution

In response to needs identified by mid-career and part-time students, and due to market demand from off-campus students, several of our geospatial information courses will be offered through distance education modes. Many widely dispersed students are particularly interested in taking the core remote sensing modular five-week courses at a distance. GsIS technology and its graphic-based content appear to be particularly amenable to being served via the internet and other distance media. Most of the course materials already exist in a digital format. The UW is very supportive of distance education innovations and provides resources through grants, technical expertise and facilities. The market for students to either just take a few critical courses, or to minimize the time they must spend on campus obtaining a degree, appears to be extremely good given the number of inquiries we have received to date about such opportunities.

In the year since the Professional Masters Degree Option was added to our established Research Masters and Ph.D. degrees, applications have increased by a fourth. Of those two-thirds applying for a Masters Degree program, requests for admission to the new Professional Masters predominate. Hence, we are confident that the new option will continue to be attractive to both students and employers interested in an applications-oriented geospatial degree.

4 IMPLEMENTING A COMMERCIALLY-ORIENTED COMPONENT WITHIN A TRADITIONAL RESEARCH AND DEVELOPMENT PROGRAM

4.1 Background

Another major influence on our overall teaching and research program has been the dawning of the high resolution commercial remote sensing era. Beginning some five years ago, we looked for opportunities to complement our traditional "academic" R&D program (focused primarily on natural science, environmental monitoring, and natural resource management) with a commercially-oriented component. We actually began pursuit of this goal in 1966 through our involvement in an innovative program called the Affiliated Research Center (ARC). This program is organized and managed by NASA's John C. Stennis Commercial Remote Sensing Program to provide US companies a no exchange of funds opportunity to examine the application of current and future remote sensing technologies in their businesses. UW/ERSC is one of nine university ARCs.* Each university conducts four ARC partnership projects each year. These projects are typically 6-9 months in length, designed to be prototypical in nature, and consistently lead to new methods or techniques that an industry partner can incorporate into their operations by developing in-house capability or by enlisting the services of a remote sensing value added service provider.

4.2 Project Impacts

The UW experience has a number of unique aspects that have driven the success of the program. Faculty investigators representing some 15 different departments are available to consult on topics ranging from digital photogrammetry to GIS, GPS, data integration, economics, business management, and commercial sector-specific applications. This faculty mix allows project access to a range of ideas and perspectives much wider than traditional geospatial information technology boundaries. Additional institutional relationships have been established between UW and numerous administrative units, laboratories, state government agencies, and other organizations in an effort to bring a broad perspective to bear on commercial firm recruitment, project implementation, and technological impact. The concept of ARC has become sufficiently important at the university administrative level to convince six separate units within the university to contribute matching support (financial and in-kind) during the first three years.

Additionally, UW now has a number of critical "lessons learned" about corporate-university partnerships that have encouraged both further fundamental research in geospatial information technologies and commercialization of same. All ARC projects at UW feature a modest objective, mutually chosen by the university and the commercial partner. Then, throughout the 6-9 month relationship, both parties lend their expertise to enhance the project based on the potential future value to potential customers. From the initial meetings to the end of the project, the technological implications of the project are discussed in terms of both organizational development (i.e., Will you need to hire more people? Will this change your corporate focus?) and financial implications of the technology. In a sense, the university is offering an accelerated, targeted "practicum" for entry-level partners who presumably will then become good customers for spatial information products and services in the future.

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*ARC Program sites are presently located at the University of South Carolina, San Diego State University, Utah State University, University of Wisconsin-Madison, State University of New York of Environmental Science and Forestry, University of Nebraska, Oregon State University, University of New Mexico, and Brown University.

What has been the response to the ARC partnership opportunity at the University of Wisconsin-Madison? In a word, “overwhelming”. Over 140 commercial firms have shown interest in the program during the last three years. Application ideas have ranged from use of Shuttle Imaging Radar (SIR) data for forest volume estimation to use of hyperspectral data in precision agriculture, environmental impact analysis and change detection for highway expansion, risk management assessment, telecommunications, software development, and others.

Through the ARC process, commercial firms, faculty researchers, and graduate students are working together in a “learning laboratory” setting to find innovative solutions in a range of applications. The depth and breadth of the process is a multi-directional domino effect that results in (1) researchers asking better basic research questions about spatial technology; (2) graduate students becoming equipped with technical AND business problem-solving skills; and, (3) corporate firms, with new tools and skills, able to offer better products at lower cost. Based on the success to date, UW and NASA have committed to extending the program for the next five years.

5 RESAC: AN INTER-INSTITUTIONAL APPROACH TO EXTENDING EOS-ERA REMOTE SENSING TECHNOLOGY BEYOND THE GLOBAL CHANGE RESEARCH COMMUNITY

5.1 The RESAC Program

Since early 1999, UW/ERSC has also participated in NASA’s Regional Earth Science Applications Center (RESAC) program. This program was created as part of the Earth Science Enterprise (ESE) to extend remote sensing technology to a user community beyond the traditional global change research community and into the natural resource management and commercial sectors. Participating researchers hope to develop technological applications to analyze the Earth as a system and to extend application of the scientific tools used in this process to a broader user community. Remote sensing data are assisting in understanding and delineating natural and anthropogenic changes at local-to-regional scales using models, specialized algorithms, and methodologies integrating remote sensing and other geospatial technologies. Facilitation of new technological applications will be carried out via internet transfer, partnering with public sector organizations, and educational workshops. Program emphasis is on problems of regional geographic scale and significance.

5.2 Upper Midwest RESAC

The Upper Midwest RESAC is a joint research effort formed from the Upper Great Lakes RESAC, led by the University of Minnesota (UM) and partnered with Michigan State University (MSU), and the UW, and the Midwest Center for Natural Resource Management, also at UW. Each institution is collaborating with public sector entities such as state departments of natural resources (DNR) and federal agencies such as the U.S. Forest Service and Natural Resource Conservation Service (NRCS). Research is concentrated in four foci of regional interest including agriculture, forestry, land use and land use change, and water resources. The goals of the institutions, public sector partners, and stakeholders within these foci are to apply remote sensing imagery in a way that improves existing methodologies or generates completely new approaches to challenging problems by visualizing solutions at scales only possible from satellite and aerial multi- and hyperspectral remote sensing platforms.

5.3 Representative Research and Demonstration Efforts to Date

Representative pilot projects in each of the four RESAC research foci follows:

<u>Agriculture</u>: Research is being conducted in association with studies coordinated by UW’s Plant Pathology Department. This research deals with determining the relative importance of disease spore dispersal for spatial and temporal development of late blight (*Phytophtora infestans*) in potato crops of the Wisconsin Central sands region. Analysis to date suggests that multispectral imagery can be used to identify the spatial extent of potato field anomalies which may be related to late blight infestation and other diseases. Image processing commenced on Landsat and orthophoto data sets of the area, and digitization of agricultural field boundaries has been undertaken and will be integrated into a GIS model of prospective disease development. Ultimately, the results of the project should reduce the need for harmful, costly chemical treatments when guided by the prospective model.

<u>Forestry</u>: Forestry research is focusing on software development in processing of radar interferometry data, 1) for interferogram phase filtering and phase unwrapping, and 2) to precisely determine the length and orientation of the SIR-C orbital interferometric baseline, using least-squares analysis of a set of ground control points. The first program includes an iterative method for phase unwrapping, in which a first approximation of the DEM is created at a low spatial resolution, and then is used to assist in unwrapping the phase data at higher spatial resolution. The second

program is required for conversion of interferometric phase differences to elevations (as high precision baseline geometry must be established with increased accuracy over the platform ephemeris data). Current results indicate that even at the relatively long wavelength of 24 cm, within the final DEM there are substantial positive biases in elevation estimates in forested areas. In at least one of the cases examined so far, this systematic phase difference bias appears to be significantly greater than the level of random error in the surrounding area. We are investigating means to correct DEMs for such bias and to potentially use the observed bias to predict timber volume parameters.

Land Use and Land Use Change: Research on land use change detection is following the lead of a recently completed NASA ARC project. Multi-date land cover classifications have been prepared for a study site focused on the Town of Scott, Wisconsin, located in a rapidly developing area northeast of Green Bay, Wisconsin. Complementary 1986 and 1998 image data for the project have been supplied by SPOT Image Corporation, and are being applied to computer models in facilitating "resource smart" land use planning; planning with the objective of maintaining ecological integrity of developing landscapes. Numerous change detection procedures are being tested with real and virtual change models developed at UW-ERSC and MSU. Comparison of unsupervised classification with change imagery from the Delta Transformation procedure (Lillesand and Kiefer, 2000) is being conducted.

Water Resources: Development of new methods for determining lake trophic status and lake classification is focusing on several Wisconsin lakes in Jefferson, Vilas, and Oneida Counties using Landsat TM data. Imagery spanning late summer to early fall, 1984-1993, are being analyzed for a variety of image statistics. Atmospherically normalized spectral reflectance trajectories have been extracted for each lake over the ten-year time frame. These reflectance trajectories show that: (1) there is a range of reflectance values across the study site; (2) most area lakes' reflectance remains relatively constant from year-to-year; (3) however, some of the lakes experience substantial reflectance changes during the ten-year period. Research will continue to develop and evaluate multi-temporal spectral trajectories as an aid to lake assessment and classification. Additional lakes and imagery dates will be added to the database, and analysis of field data collected for current study lakes through the North Temperate Lakes Long-Term Ecological Research (LTER) site will be performed. In fact, we are mid-stream in the planning of a new Satellite Lake Observatory Initiative (SLOI) that will involve the combined use of MODIS and Landsat data to monitor lake spectral properties on a regular basis regionally. Among other things, this involves the goal of developing "lake spectral indices" akin to the NDVI and other indices common in vegetation applications. We are also exploring the use of instrumented buoys to broadcast in-situ water quality measurements via the internet for empirical calibration of satellite images.

6 CONCLUSION

It is a severe understatement to say that the modern climate in which geospatial education and training resides is a changing one. We are faced with a whole new paradigm–technologically, institutionally, and ecologically. The new paradigm dictates that higher education revisit how best to adapt its teaching, research, and outreach programs not only to advance the theory and technology of geospatial information, but also to maximize its scientific, social, and commercial value.

We have highlighted only a few of the changes we are making at UW in response to the demands of the new geospatial information education and training paradigm. We hope that our sharing of the rationale and experiences associated with these initiatives is helpful to others contemplating similar activities.

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INTERNET ADDRESSES

UW-Madison:	http://www.wisc.edu/
IES:	http://www.ies.wisc.edu/
CEE:	http://www.engr.wisc.edu/cee/
ERSC:	http://www.ersc.wisc.edu/ersc/
Environmental Monitoring Professional Option:	http://www.ersc.wisc.edu/EMPP/
ARC:	http://www.crsp.ssc.nasa.gov/arc/arcmain.htm
Upper Midwest RESAC:	http://resac.gis.umn.edu/