Preparing Students for Careers in Remote Sensing Applications

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and NASA Earth Science Enterprise
Preparing Students for Careers in Remote Sensing Applications

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Executive Summary
This workshop brought together university faculty and employers to explore how colleges and universities can best prepare their graduates for careers in fields that will increasingly rely on applications of remote sensing technology. Session topics included: an examination of current and future workforce needs; best practices in higher education for teaching remote sensing and related topics; anticipated technical developments in remote sensing relevant to developing applications; internships and externships; engaging a diverse student population; and ongoing communications relating to employment needs and student preparation for entry level positions.

Workshop sessions included keynote presentations by NASA personnel, academic leaders and industry representatives, panel discussions, and working group sessions focused around questions relevant to curriculum design and program planning.

Background
Over the past few years, technical advances in remote sensing coupled with the development of geographic information software and greater availability of data at usable scales have contributed to development of remote sensing applications in a wide range of new sectors. The growth of the commercial remote sensing industry, as well as the increase in data provided by federal agencies, is expected to continue to foster the expansion of existing data applications and the creation of new ones. As federal agencies and professional organizations work to facilitate the transfer of technology from the realm of exploratory research to user-oriented applications, opportunities for entry-level positions that require a working knowledge of remote sensing theory and applications will grow.

A number of studies have examined anticipated workforce needs in remote sensing and geographic information systems-related fields (e.g., American Society for Photogrammetry & Remote Sensing (ASPRS), Interagency RS/GIS workforce initiative) in the near and long term. Although these studies do not predict a near-term increase in workforce demand, many remote sensing professionals believe that the continuous development of new applications will result in at least a slow, steady rise of professional positions in the remote sensing industry (See, for example, the ASPRS Career Brochure). Further, any step function increases in workforce demand would be nearly impossible to predict much in advance, as these would most likely be related to growth in new industry sectors (Transforming Remote Sensing Data Into Information and Applications, National Academy Press, 2001).

These studies indicate that colleges and universities should examine curricula and pedagogy in fields related to remote sensing to determine whether they are adequately
preparing students for employment in this developing industry. In addition, there is also a need for retraining of the current workforce in industries that are moving toward implementation of remote sensing applications. This training may be provided in a variety of formats including university extension courses, workshops, externship/cooperative programs, or in-service training. Ongoing communication among employers, agency personnel and university faculty would be helpful in determining the effectiveness of current curricular offerings and the development of new courses and programs to meet expanding needs. The ASPRS has begun this conversation among their members with a major focus on image processing and providing curricular recommendations and updated information about career opportunities. It is our intention to broaden that effort by including additional topics related to remote sensing science.

The development of practical applications for remote sensing and the attendant demand for a specially trained workforce come at a time when universities are transforming their undergraduate programs to include a greater emphasis on project-based courses and opportunities for independent research. These new pedagogical approaches lend themselves particularly well to studies that are interdisciplinary in content and have a variety of applications in new and developing areas. Courses in remote sensing theory and applications can draw on Web-based data and processing tools, providing rich resources for student projects. These projects can also incorporate an emphasis on local issues, such as resource management, urban planning, and others, thereby linking university resources to community needs and opportunities. Internships at agencies and industry sites will help to provide context for classroom learning, and will also allow feedback between the hosts and the universities regarding student preparation and performance. As the workforce becomes increasingly diverse, it is important to provide opportunities for students from previously underserved and underrepresented groups to enroll in degree programs that prepare them for employment in jobs that require GIS and remote sensing skills.

**Working Group Recommendations**

Working Group 1 focused on developing recommendations for university-level courses and degree programs that prepare students for work in fields that include remote sensing theory and applications. Specifically, this group was asked to consider what kinds of skills and conceptual knowledge are most needed for entry-level jobs, and what types of courses and/or degree programs might satisfy those needs. Detailed notes on the concepts and skills needed are found in the group presentations in a following section. The group’s overall recommendations included:

- Remote sensing is a tool, not a discrete academic department. It should be integrated into existing disciplinary curricula and into interdisciplinary courses and activities in a way that is driven by content and application.
- Institutions should review and coordinate their curricula in all related fields to see where remote sensing can be introduced at a multidisciplinary/interdisciplinary level (environmental sciences, physical sciences, forestry, geography, planning etc.). NASA should stimulate the infusion of remote sensing sections into
fundamental courses through specialized curriculum development grants and education grants attached to research.

- Curriculum should be linked directly to workforce needs.
- Encourage the recognition of minimum standards for knowledge, skills and abilities in people trained in remote sensing, including an accreditation program with beginning and specialized levels.
- High school advisors and teachers should be encouraged to ensure that students have fundamental skills in science, math and technology.
- Develop a *Careers in Remote Sensing* brochure to stimulate interest in remote sensing fields and awareness of the preparation needed for those careers.

Working Group 2 considered the issues of recruiting and preparing students for remote sensing-related careers specifically through internship and research experiences. This group’s recommendations included:

- Establish a national remote sensing internship program for undergraduates in related disciplines modeled on the NASA Undergraduate Student Research Program and the DEVELOP program. USRP, in particular, recruits its national applicant pool primarily through Space Grant universities and Historically Black Colleges and Universities (HBCUs) to match students to suitable positions at NASA facilities. This model may be expanded to include industry and local government internships, providing employers with access to a high quality pool of diverse applicants and stimulating interest in these careers among students in related fields.
- Create a remote sensing problem bank that allows students to address real needs and applications. Opportunities might be provided for students to present solutions in appropriate forums (team-based competitions or presentations at professional meetings).
- Use connections with Space Grant and minority-serving institutions to engage many colleges and universities in supporting students with access to mentors and to the resources of the remote-sensing industry, professional societies, and local and national government agencies.

Working Group 3 looked specifically at links between educational programs and workforce needs. Among that group’s recommendations are:

- Distance learning through the use of Internet technology has an important role in the distribution of ideas and lessons to widely separated community colleges and universities. Distance learning environments can take advantage of the unique expertise available only at one location and extend that expertise to a broad audience. To support online courses and lessons, NASA could help negotiate with software companies to provide remote sensing and GIS software licenses at minimal cost.
- NASA instrument teams could be charged with certain educational tasks, such as using standardized data formats and providing sample data sets and examples of applications so that instructors can utilize the latest data and technology in the
classroom. Proposals could be entertained to obtain data for educational purposes through NASA data buys.

- Create an introductory level course in remote sensing project design utilizing active pedagogical approaches to engage a diverse population of students. The course should provide basic knowledge and applications. Develop further courses in relevant disciplines and interdisciplinary settings at more advanced levels.
- NASA representatives can help raise the profile of remote sensing activities at universities by visiting university presidents and other officials to promote development of research and educational programs in these emerging fields.

Working Group 4 focused on communications among university, industry and agency leaders, and how college and university faculty in particular can remain informed about workforce needs. Recommendations included:

- Use an online newsletter or e-mail list open to those in industry, government, and academics. This would require an organization to take responsibility for the management of such a resource.
- Professional societies need to be introduced to undergraduates, and vice versa. Have sessions with local chapters where students can attend and find information and mentors, and see the latest applications.
- Appoint adjunct faculty from industry or agencies to co-teach in college or university settings; invite students to industry or agency sites for tours and internships.

A description of the workshop sessions follows. Full presentations by the keynote speakers and notes from the working group discussions are contained on the accompanying CD.
Workshop Agenda

Wednesday, August 14

5:30-7:00 p.m. Welcoming Reception and Early Registration
New England Center Gallery

Thursday, August 15

Day one introduces workshop goals, themes to be explored, reviews workforce needs, status of remote sensing education and best practices

7:30 a.m. Registration and Continental Breakfast – New England Center Gallery

8:00-8:30 Welcome and Introduction: David Bartlett, New Hampshire Space Grant
Charge to Attendees: Ming-Ying Wei, NASA Headquarters and JM Wersinger, NASA Space Grant – Berkshire Room

8:30-9:30 Presentation: “New Directions in Remote Sensing Education” Mike Goodchild, University of California at Santa Barbara

9:30-10:30 Presentation: “Emerging Issues: New Challenges for Understanding our Changing Planet” Berrien Moore, University of New Hampshire

10:45-12:15 Panel #1: Remote sensing employers speak about near and long-term needs and expectations of entry level workers: Mark Brennan, Space Imaging; John Iiames, EPA; Patrick Bresnahan, Richland County, South Carolina

12:15-1:15 Lunch – New England Center Dining Room

1:15-2:00 Presentation: “NASA’s Perspective on Opportunities for New Applications of Earth Science and Implications for Workforce Development” Ron Birk, NASA Earth Science Enterprise

2:00-3:30 Panel #2: University faculty perspectives on remote sensing education and training: Pamela Lawhead, University of Mississippi, Dan Civco, University of Connecticut, James Campbell, Virginia Tech

3:30-3:45 Break

3:45-5:00 Table discussion of session themes for second day

5:00-5:30 Report out, organizational information for second day
Friday, August 16
*Day two focuses on small group work on proposed questions/themes that have been refined on Day one. Themes will address goals of workshop. Attendees may narrow focus or replace some of these themes based on Day one work.*

7:30 a.m. Continental Breakfast – Gallery – New England Center

8:00-8:15 Introduction to Day Two: Janice DeCosmo, Washington Space Grant

**Berkshire Room**


Patrick Bresnahan, Richland County, SC

8:35-8:50 Remarks from John Dwyer, USGS, on the remote sensing workforce needs and preparation from agency standpoint, followed by general discussion


9:35-10:15 Group Discussion and Charge to Working Groups

10:15-10:30 Break

10:30-12:00 p.m. Breakout Working Groups

12:00-1:30 Lunch – New England Center Dining Room


2:30-2:45 Break

2:45-4:30 Breakout Working Groups Continued

4:30-5:00 Recap, Announcements, Adjourn

Dinner on your own
Saturday, August 17  
*Day three refines work of day two and provides closure*

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<tr>
<th>Time</th>
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<tr>
<td>7:30 a.m.</td>
<td>Continental Breakfast – Gallery New England Center</td>
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<td>8:00-8:30</td>
<td>Review Day Two, charge for final working group session, organization of working group input for final report - <strong>Berkshire Room</strong></td>
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<td>8:30-9:45</td>
<td>Working Group Session</td>
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<td>9:45-10:00</td>
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<td>10:00-11:00</td>
<td>Working Groups Report Out – <strong>Berkshire Room</strong></td>
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<td>11:00-11:30</td>
<td>Discussion</td>
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<td>11:30-12:00 p.m.</td>
<td>Closing Remarks – Bartlett/DeCosmo</td>
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New Directions in Remote Sensing Education
Michael Goodchild, University of California at Santa Barbara

We face three challenges in remote sensing education. The first is to identify the fundamental and persistent principles of the field. These principles will serve as the conceptual core of any curriculum. Core principles are ideas that will still be true in 20 years and will be fundamental to any future technological innovation. We need to provide students with a robust conceptual framework so they can fit in new information as they continue to be lifelong learners.

Second, traditional instruction must be reinvented to take advantage of new instructional technologies, to better integrate K-12 learning, to reach a diverse population of students with varied learning styles and approaches, and to allow resources to be shared among instructors and students. Our curriculum should include hands-on instruction with real problems and case studies. More and more people, especially minority students, are getting their first two years of higher education through the community colleges. We must create vertical integration in grades K-16, including community college curricula. There could be more sharing of instructional resources among these faculties, leading to the question: How do we build an infrastructure for sharing?

Third, any introduction of remote sensing concepts and tools needs to focus on the solution of problems as the primary motivation to its use, whether in science or society, e.g., spatial decision support, and accuracy assessment. Remote sensing must be taught as a means to an end that is relevant to students and society.
If we visualize the users of remote sensing as a pyramid, the narrow top would represent the “technocentric” users, and the bottom level would represent the 10 million people who encounter it through a user-friendly interface as they do their daily tasks, such as finding directions on Mapquest. Two of the big questions facing educators are: Who do we want to engage—and at what level in the pyramid? How do we move people up the pyramid?

There is also a question of many sources of available data. Educators and users must decide how to access needed data, how to evaluate its fitness and how to deal with misalignment. Another persistent issue is how providers of data organize it. There are currently no comprehensive search engines for geospatial data. There are also significant accuracy issues and there is always a problem with misfits when combining different data sets. One current project that seeks to provide a resource for geospatial data is the Alexandria Digital Library Project, a map and image library organized by geographical location. The library is located online at www.alexandria.ucsb.edu/.

The value of a geolibrary in the classroom is low without the tools for using the data to address questions relevant to concepts and applications. To take full advantage of digital data, we need computational models that can be used to process the data to support inquiry and applications. An emerging resource is DLESE: Digital Library for Earth System Education, a digital archive of learning resources directed by the community of scientists, teachers, etc. DLESE can be found at: /www.dlese.org/. Eventually there might also be a mechanism for peer-to-peer resource sharing in the style of Napster (i.e. a grassroots system with no central authority).

Emerging Issues: New Challenges for Understanding our Changing Planet
Berrien Moore III, University of New Hampshire

Berrien Moore is engaged in research on climate change attributed, in particular, to changes in the concentration of atmospheric carbon dioxide. He reviewed the historical record of atmospheric carbon dioxide concentrations and its relationship to climate and the greenhouse effect. While it is widely recognized that man-made carbon dioxide is
contributing to an increase in atmospheric concentrations of carbon dioxide, the sources and sinks for global carbon are not all well understood.

Current research with NASA JPL is focused on developing an active carbon dioxide observatory to detect column-integrated carbon dioxide concentrations to a very high precision from a satellite-based instrument in sun synchronous orbit. This is an exciting development in new remote sensing technology that will contribute greatly to our understanding of the Earth system.

Moore notes that it is important to begin thinking about ways to excite kids about the math and science, and how those studies can lead to advances in scientific methodology such as remote sensing. Educating teachers on the technology and its usefulness to understanding our planet is important with regard to their ability to teach and inspire their own students, but it is also important to them as citizens, so they can appreciate the utility of research in this critical area. NASA is the primary agency supporting many advances in remote sensing science and applications.

**NASA’s Perspective on Opportunities for New Applications of Earth Science and Implications for Workforce Development**
Ronald Birk, NASA Earth Science Enterprise

The mission of NASA’s Earth Science Enterprise (ESE) is to develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. ESE supports work in basic science, applications and education to
meet its mission. NASA research and satellite observations enable the global characterization of factors forcing the climate system and their relative strengths.

Specific areas of active research programs include water and energy cycle, carbon cycle, weather and climate, chemistry-climate connection, and solid earth and natural hazards. Some of the critical questions that drive the enterprise’s work are: How is the global Earth system changing? What are the primary forcings of the Earth system? How does the Earth system respond to natural and human-induced changes? What are the consequences of changes in the Earth system for human civilization? How well can we predict future changes to the Earth system?

For example, one of NASA’s newest missions, GRACE (launched in March, 2002), will map Earth’s gravity field and its variations with a precision never before accomplished. GRACE will map the variation in Earth’s mass due to mountains, valleys, oceans, and caverns, and provide information on subtle gravity changes due to shifts in the ocean, runoff and ground water storage on land, as well as mass exchange between ice sheets, glaciers and the oceans.
NASA is also interested in developing applications that use remote sensing data to address critical national, regional, and local issues such as energy forecasting, carbon management, agricultural competitiveness, aviation safety, community growth, homeland security, public health, disaster management, coastal management, and air and water quality management. The economic impacts of this knowledge could be tremendous. The cost of electricity, for example, could decrease by at least $1 billion annually if the accuracy of 30-hour weather forecasts improved by 1 degree Fahrenheit. Operating aircraft using advanced Synthetic Vision Systems at just 10 airports in the United States could result in projected annual savings of over $2 billion. In these applications, scientific models and remote sensing data are combined using high performance computing and visualizations for decision support for government agencies and society.

The Earth Science Enterprise supports both space-borne, airborne and in situ measurement systems to improve our knowledge of the Earth system. A film presentation at the workshop illustrated new instrument developments and applications in several of the areas of interest noted above. In addition to contributing to the scientific understanding and development of applications, NASA’s Earth Science Enterprise is also interested in improving public awareness, appreciation and understanding of Earth system science and encouraging the pursuit of careers in science and technology using unique NASA content and resources. NASA provides resources to influence each stage of the educational pipeline, promoting understanding and interest in the Earth system through teacher-reviewed curriculum materials for grades K-12, and through curricula for colleges and universities. The agency also provides graduate fellowships and early career and education grants to new professionals. In addition, NASA works with informal educators at museums, and with organizations such as National Park Service, Girls Scouts, and libraries to increase public literacy in Earth science.

**A Model for University-Industry Collaboration in Remote Sensing Workforce Development**
Luke Flynn, University of Hawaii
Hawaii Space Grant Consortium has encouraged university and industry collaboration on workforce education through the Rural Workforce Development Project. The state of Hawaii has close military ties to imaging companies and there has been a huge expansion of activities in the state since 9/11. NovaSol Inc. and STI Industries are two of these new companies, each currently employing about 50 people.

The Consortium polled 70 businesses and government agencies that use remote sensing data. The survey asked about the levels of expertise required, applications used, future resource needs and most efficient method of education (i.e. short courses, workshops, distance learning). Most respondents said that their greatest need was for master’s level professionals. They wanted software engineers to create applications and engineers with signal processing skills. Most employers preferred multidisciplinary training, including courses from electrical engineering, programming, geology, and geography, to a focus on a single discipline.

The survey has stimulated the creation of a multidisciplinary master’s program with direct links to the local remote sensing industry through student apprenticeships. The two companies currently participating in the program, NovaSol and STI, have a forecasted need for 20 to 40 graduates in new positions over the next two years. Students who successfully complete the master’s program will automatically be considered for these jobs.

The multidisciplinary remote sensing master’s program works as follows:

- Year 1: The student receives a fellowship paid by Hawaii Space Grant Consortium and the federal Rural Workforce Development Project (RWDP). The student takes courses in signal processing, remote sensing, geography, and computer science/software development.
- Year 2: The student takes one to two classes and spends the rest of his/her time on a project. The student’s salary is split with 80 percent funded by the Consortium and RWDP and 20 percent coming from industry.
- Year 3: The student graduates and is hired as a trained employee.

Among the mutual benefits of this degree program is the establishment of a link between industry and the university so that it is now much easier for university faculty and industry personnel to cooperate on joint research projects.

An important component of Hawaii’s approach is the integration of remote sensing concepts and projects in K-12 outreach activities, such as Future Flight Hawaii teacher education and family programs. These activities are designed to teach basic science concepts and also foster interest in new technologies used to understand the earth system.

**Remote Sensing employers on near- and long-term needs and expectations of entry level workers**
Patrick Bresnahan, Richland County, South Carolina; Mark Brennan, Space Imaging; John Iiames, EPA; John Dwyer, USGS.
Patrick Bresnahan, Richland County, South Carolina

Local governments are already using remote sensing technology, but not to its fullest potential. Data collected from remote platforms could be utilized to evaluate land change, air pollutants, and water quality as impacted by the interaction of land and infrastructure development or modification. It also could be used for parcel valuation for taxation, infrastructure data, permit management and structural analysis.

Bresnahan’s core staff is drawn from the undergraduate fields of geography, geology, environmental science, planning and architecture, computer science and civil engineering. Richland County users come from a wide range of interest areas including insect control, environmental control, and planning. The difference between the effectiveness of staff members is the difference between training and education.

The skills sought in new hires include software proficiencies (Arcview, etc) and a basic understanding of GIS, database management (Excel, Arcview tables, etc), minimal cartography, and fundamentals of aerial photo interpretation. Recent graduates still have very little understanding of the basic principles of remote sensing. Students are not seeing that basic education in physics, mathematics, and computer science is needed in order to interpret current remote sensing applications appropriately, and to allow workers to stay abreast of changes in the field as they occur.

In addition to an understanding of basic remote sensing concepts, employers need job candidates who are familiar with the fundamentals of databases. They should know database structure and relational concepts, efficiencies (indexing) and maintenance, and data integration (conversion, Access/SQL, etc). They should also know basic computer science. Those skills include file management and access, fundamentals of networks/management, and knowledge of hardware/software/infrastructure.

Mark Brennan, Space Imaging

Space Imaging is a leading supplier of visual information products and services derived from space imagery and aerial photography. The company launched IKONOS™, the
world's first commercial one-meter resolution Earth imaging satellite on Sept. 24, 1999. Other Space Imaging products are produced from Indian Remote Sensing satellites, U.S. Landsat satellites and Canada's RADARSAT. Space Imaging also delivers aerial-derived imagery products collected by its own Digital Airborne Imaging System (DAIS-1™). The company employs about 400 people, the majority of whom are cartographers. Other employees include computer scientists, application developers, geographers, and specialists in domains such as forestry and geography. Most hold advanced degrees and work on applications, mainly in the fields of agriculture, forestry and urban planning.

Problem solving is the most important skill needed in new hires. Technical degree or certificate programs, especially community college level, are needed in areas such as photogrammetry and surveying to fill positions such as stereo plotter operator. In the area of four-year programs, Brennan echoed the course list covered by Bresnahan, and suggested additional courses in calculus, physics, computer programming (C, C++, Visual Basic), databases (SQL), and statistical geophysics, as well as a familiarity with tools such as MATLAB. In the advanced degree area, he would like to see more focus on problem solving and developing applications.

Brennan was enthusiastic about internships and work-study programs, and predicts more opportunities in remote sensing fields will emerge. Space Imaging currently takes on 10 students each year, working through the career counseling offices to recruit students with appropriate backgrounds. He recommended moving toward certification through ASPRS and anticipated that the market for remote sensing products would grow about 10-13 percent per year.

John Iiames, U.S. Environmental Protection Agency (EPA)
The Environmental Protection Agency hired heavily in 1972. Those employees are now reaching retirement age and many will be gone in the next three to five years. The wave of retirements is not confined to the EPA, either. It is predicted that in five years 250,000 positions in federal agencies will open up due to retirements. Fifty percent of those in NASA will be in remote sensing areas.

In addition, to the retirement impact, there are changes in the agency's direction since 1998 that require new employees to have different skills and knowledge than those whom they are replacing.

The EPA hires a number of interns from local universities. Ideally, new hires should have strong backgrounds in trigonometry, matrix algebra and physics, and effective communication skills, especially writing. The agency also looks for evidence that employees have the ability to transition between computer platforms and data types as they will be continuously faced with changes in software and hardware over their careers. In addition, content specialists in hydrology, soils, and geology are needed. EPA is currently interested in students with experience in computer modeling of complex terrain, air and water systems. For EPA, the most important emerging issues are human health issues.
The EPA hires more employees with advanced degrees than those at the baccalaureate level. Most employees with advanced degrees are initially hired through internships and a post-doctoral program. In the past, new hires usually had doctoral degrees, but in the near future, EPA will probably bring in more people with master’s degrees. He noted that the Environmental Careers Organization (ECO), based out of Boston, places EPA interns. For more information, go to www.eco.org

John Dwyer, U.S. Geological Survey (USGS), EROS Data Center
New funding should be used to promote new uses, new users and a new understanding of remote sensing, invest in new technologies and applications, and develop prototypes of products and services. Workforce preparation for remote sensing-related positions needs to include studies in: geography; Earth and natural sciences; fundamentals of math, statistics and chemistry; physics/geophysics and principles of remote sensing; training in and knowledge of tools, including digital image processing and interpretation, and geographic information systems.

More specifically, USGS staff hires should have experience with airborne and satellite data; image processing and GIS software; programming languages such as C++, an object-oriented language, HTML, or XML; different system platforms (UNIX, Windows, OS, Linux); statistical analysis software; and radiative transfer models. Candidates should have both academic training in the theoretical base and practical experience working with real tools and real problems. Strong oral and written communication skills are needed because 90 percent of project failures can be traced to a lack of effective communication. Effective employees are able to multi-task and have a commitment to teamwork.

Weaknesses in new hires include a lack of understanding of the basic math and physics necessary to understand remote sensing. These weaknesses tend to manifest at the master’s level. The USGS has been proactive with local universities, helping to tailor coursework to meet agency needs. USGS offers undergraduate internships. These are a
great way for students to gain the hands-on training they will need to be successful. Internship placement is through the USGS human resources department.

**University faculty perspectives on remote sensing education and training**

Pamela Lawhead, University of Mississippi, Dan Civco, University of Connecticut, James Campbell, Virginia Tech

Dan Civco, University of Connecticut

In August 1999, the American Society for Photogrammetry & Remote Sensing (ASPRS) and NASA's Commercial Remote Sensing Program (CRSP) entered into a five-year agreement, combining resources and expertise to baseline the remote sensing industry; develop a 10-year market forecast; provide improved information for decision makers; and develop attendant processes.

An ASPRS survey found that the average number of students involved in remote sensing or GIS-related programs at the universities and colleges that responded was about 140, or slightly less than 1 percent of the student body population, which averaged 17,000.

Over 60 percent of those working in the field have a master's degree or better. The study found most of the workforce received some training in remote sensing through formal course work. However, employer-sponsored training is infrequent.

Pamela Lawhead, University of Mississippi

The Institute for Advanced Education in Geospatial Sciences at the University of Mississippi has been developing an online remote sensing curriculum as part of a larger curriculum development project. Lawhead, the director of the Institute, said the original goal was to offer 50 online courses in remote sensing in five years. The courses were to be multimedia intensive and targeted to support NASA’s national applications for Earth system science.

The institute received grants to buy experts’ time for a year. The first two rounds of curriculum grants have been awarded, and courses are in the design and pilot phase.
Details on the current status of the program are available on the Web site at http://geoworkforce.olemiss.edu.

James Campbell, Virginia Tech
Campbell is developing an interactive remote sensing course under the auspices of the Institute for Advanced Education in Geospatial Sciences. His research on education and geography has found a gender split in students interested in the field. The technology-heavy side of the geography drew predominantly white males. Students were split more evenly by gender in social geography. That area of the field also drew more minority students.

To interest traditionally underrepresented groups in the technology-heavy areas of the field, universities need to introduce geospatial approaches to problems earlier in the curriculum rather than wait for specialized upper division courses aimed at students who have already decided their majors. One suggestion would be to use a learning model that presented basic principles and techniques then guided students through initial case studies before introducing new cases that they could solve more independently.
Working Group Presentations

Group 1: Focus on University-level Courses and Degree Programs

Questions:
1. What kinds of skills and conceptual knowledge are most needed for individuals entering the workforce in earth remote sensing-related areas today? In five years?
   - Knowledge of underlying physical concepts used to design instruments and interpret data?
   - Knowledge needed to design hardware for instrumentation or data analysis?
   - Programming skills for management and analysis of large data sets?
   - Familiarization with a broad array of current applications of remote sensing data?
   - Knowledge of developing trends in instrument capabilities and data handling?

2. How can colleges and universities best provide basic and advanced education in earth remote sensing to produce graduates prepared for entry into the workforce? Groups should develop guiding principles (“must haves”) and strategies for the development of the following:
   - Entry-level courses to cover basic concepts and skills, explore applications?
   - Intermediate-level courses to deepen conceptual understanding and skills?
   - Capstone courses for related majors or earth remote sensing emphasis within related departments and fields?

3. How can college and university faculty remain informed about remote sensing workforce needs? If a continuing dialog is desirable, who should moderate and advance that conversation? How should it be structured or led? Should it be publication-based (i.e., a newsletter or web publication), organization-based (i.e. local university-industry working groups), or might it include increased collaborations via visiting researcher/faculty opportunities in industry, agencies, and universities? Externships?

Recommendations:
1. Institutions should review their curricula to see where remote sensing can be introduced at a multidisciplinary/interdisciplinary level. The emphasis should be on fundamental concepts. Possible sources of funding include NASA curriculum development grants and curriculum development money attached to research grants.

2. Remote sensing curricula should be coordinated across the institution. As much as possible, remote sensing education should be integrated into the existing curricula.
3. There should be encouragement to recognize minimum standards for knowledge, skills and abilities for people trained in remote sensing. Courses and skills might include basic statistics, mathematics (trigonometry, linear algebra, matrix algebra, calculus), communications, and team management. One option might be to offer accreditation. The American Society for Photogrammetry and Remote Sensing (ASPRS) is looking into this option.

4. Any remote sensing curriculum should be responsive to workforce needs. Therefore, the remote sensing community should lead this workforce effort.

5. The level of remote sensing specialization is a sliding scale and the depth of specialization is variable.

6. Remote sensing is a tool, not a discrete academic department. Remote sensing education should be managed in a “virtual” academic program as an interdisciplinary curriculum.

7. High school advisors should be encouraged to make students going on to higher education institutions aware of certain courses and career paths including Earth remote sensing education. One tool to accomplish this would be broad distribution of the Careers in Remote Sensing brochure created by ASPRS.

**Group 2: Student recruitment and internship & research experiences**

Questions:

1. How can colleges and universities work with industry to provide internship experiences for students that introduce them to opportunities and help them to advance their knowledge and skills? What is the value of student interns to industry, agencies, and what can universities do to prepare students to get the most out of internships? How can internship and research opportunities be used to develop workforce and stimulate interest in earth science and remote sensing? Should there be a regional or national clearinghouse for these opportunities? What might it look like? How could it be run?

2. How can colleges and universities recruit a talented and diverse pool of students to academic programs that prepare them for future employment in Earth remote sensing related fields?

3. How can college and university faculty remain informed about remote sensing workforce needs? If a continuing dialog is desirable, who should moderate and advance that conversation? How should it be structured or led? Should it be publication-based (i.e., a newsletter or web publication), organization-based (i.e., local university-industry working groups), or might it include increased collaborations via visiting researcher/faculty opportunities in industry, agencies and universities? Externships?
Recommendations:

1. Access funding to engage the Space Grant network to establish a national internship program in remote sensing for undergraduate students.

The Space Grant network is uniquely poised to:
- Engage its more than 500 institutions of higher learning in all 50 states, Puerto Rico, and the District of Columbia.
- Work with HBCU’s and other minority-serving institutions, many of which are Space Grant members and partners.
- Build on its demonstrated successes with NASA internship programs such as NASA Academy and USRP, as well as state-based programs.
- Build on existing partnerships with state-based remote sensing practitioners (industry, and local/state and federal government organizations).
- Partner with professional societies such as ASPRS, MAPPS, AGU, NSGIC and ASCE to establish and promote internships/externships.
- Utilize intern program alumni as role models, mentors and educators in the wide range of Space Grant K-16 activities.

2. Space Grant should support ongoing NASA programs that engage undergraduate students in remote sensing applications such as DEVELOP. NASA should look for ways to integrate the national Space Grant network into these initiatives. DEVELOP could engage the Space Grant network in recruitment, linkages to state/local partners, presentation opportunities, higher visibility, and access to a diverse population of students nationwide.

3. Create an electronic resource and communication tool to facilitate awareness and networking among stakeholders in the remote sensing community. Contents could include:
   - Career information and opportunities
   - Links to related professional societies
   - Database of internship opportunities
   - Information on NASA Earth Science programs
   - Links to funding opportunities.

4. Establish a remote sensing problem bank that allows students to address real needs and applications. These would also provide opportunities for students to present solutions in appropriate forums.

5. Create externship opportunities for remote sensing practitioners to work with college/university faculty and students.

6. Use venues such as the following to raise awareness of career opportunities in Earth remote sensing for traditionally underserved populations:
   - Mining alumni resources as mentors, role models and program participants.
   - Utilizing past internship participants in recruitment efforts.
• Partnering with formal and informal K-12 education programs.
• Partnering with HBCUs and minority-serving institutions.

**Group 3: Focus on types of educational programs that best address workforce needs**

**Question 1:** Given what we know about the current workforce needs in earth remote sensing fields, or in agencies or industries that utilize applications of remote sensing in some or all of their work, what kinds of academic programs are best suited to preparing students for those opportunities?

a. Specialized undergraduate major degree programs?
b. Remote sensing courses integrated into more traditional degree programs?
c. Master’s level programs, following undergraduate majors in traditional disciplines (which ones)?
d. Associate degree programs?
e. Outreach to underrepresented groups?
f. PhD programs?
g. Continuing education for professionals?
h. Interdisciplinary courses and degree programs?
i. Linkages/articulation among colleges and universities, K-12, international education?

The answer to this question largely depends on the tasks that the student will be required to do as part of the job. Since these tasks can vary widely, there is no single answer for this question. Specifying particular employment opportunities may help to focus on one of the programs listed above, but there can be many examples with no single solution fitting all scenarios.

In ANY case, there is a definite need to teach principles of remote sensing and geographic information systems at a general level. All levels of entry into industrial or government jobs require an understanding of these basic principles. A series of core courses must be developed and should be taught to all candidates entering remote sensing or GIS careers. This new core curriculum would receive more attention if women and minorities show a greater interest in it. Furthermore, the value of remote sensing and GIS applications in most science disciplines should require an introductory course level knowledge of these subjects for all undergraduate program candidates. This may run up against some institutional barriers, but it is time to change this mentality. Consideration should also be given to the development of a remote sensing project design course, perhaps at the introductory level.

NASA can help strengthen university remote sensing programs in a number of ways. The most important and direct means would be for a NASA administrator or high-level designee to set up a meeting with the university president to discuss implementation of remote sensing and GIS curricula. This is important because remote sensing in U.S. universities is almost always dispersed among many units, which means that remote sensing/geospatial data may be valued within individual departments, but is not likely to be the top priority for any given dean. In some instances, faculty and departments may need incentives to collaborate. An endorsement of the significance of these activities by
high profile outsiders may help raise the visibility and the coherence of existing activities. A top-down outside push of this nature is also necessary to help overcome institutional barriers to curriculum change. The NASA representative could not only provide encouragement, but could also be prepared to provide more substantial offers in the forms of monetary grants for teaching remote sensing/GIS and content (sample courses, lesson plans, and data) for curriculum development. NASA could also encourage the development of a remote sensing community of researchers and teachers to help related faculty work in a synergistic fashion. This will help to meet the geospatial workforce need. An interdisciplinary approach is very important. Telepresence could become an important part of university higher education. In three to five years, all universities will be part of the Internet 2 (I2) network, and NASA could find ways to take advantage of this technology. NASA could also suggest a list of models of certificate programs in remote sensing and GIS so that there is some uniformity in those programs across the nation. The certificate program should include an internship component. This would ensure that there is an educational and training component in the certificate program.

**Question 2:** Do we need to know more about workforce needs in order to answer this question? How might we obtain a better understanding of workforce needs in local or regional areas?

Yes, the specific needs of employers, whether government or industry, are required in order to answer the first question. To design an efficient curriculum, one would have to know the numbers (absolute and percentages in different sectors) of the workforce needs. It would also be important to know what specific kinds of knowledge are required for specific skill sets in the job market.

To be responsive to workforce needs, universities will have to consider national needs while being responsive to the specific needs of local companies. Local companies may be the most likely employers of university graduates. Workforce needs on the national level may be determined through the efforts of professional societies (e.g. ASPRS, AGU, GSA). On the local or regional scale, determining the needs of the workforce may be accomplished through state Space Grant consortia or through the efforts of individual universities. Some state Space Grants do not have remote sensing and GIS as their institutional focus and hence would not participate in polling their local industries. Seeking feedback from alumni who have remote sensing or GIS-related jobs is another way to determine the needs of the workforce. Establishing a managed Web-based database of workforce requirements would be helpful. An accompanying list serve could provide an efficient link to universities where single responses from interested companies could be forwarded to a network of institutions.

**Question 3:** How could colleges and universities assess the effectiveness of their curricula in preparing students to enter the workforce?

There are a number of ways that colleges and universities can assess the effectiveness of their programs with respect to workforce needs. Universities can poll their alumni who have obtained remote sensing or GIS-related jobs and ask about their preparedness for entering their particular jobs. Employers can be polled to determine whether or not
they feel that their employees have been sufficiently trained. Employers also would be able to provide information on knowledge areas where employees seem to be chronically deficient. Requiring graduates of degree programs to take professional exams may be another measure to evaluate the general program curriculum. Studying alumni retention statistics and how many alumni acquire jobs in their field of study and within their local region will help to assess program effectiveness. Through their feedback on student capstone experiences, supervisors will be able to provide an assessment of individuals passing through remote sensing and GIS programs.

**Question 4:** How can college and university faculty remain informed about remote sensing workforce needs? If a continuing dialog is desirable, who should moderate and advance that conversation? How should it be structured or led? Should it be publication-based (i.e., a newsletter or Web publication), organization-based (i.e., local university-industry working groups), or might include increased collaborations via visiting researcher/faculty opportunities in industry, agencies, and universities? Externships?

Again, there are a number of possible avenues to be taken that will allow faculty to remain informed about workforce needs. Encouraging faculty/workforce personnel exchanges for limited periods of time would allow for both student trainers and employers to experience the learning and work environments, respectively. Another good option would be to encourage faculty sabbaticals at specific industries that hire graduates or at NASA centers. Student and faculty involvement in industry research opportunities or in work carried out by end users would allow faculty to assess workforce needs directly. Joint university/industry seminars and technology open houses can provide a necessary forum for interaction. These particular activities may be advertised if not coordinated through state Space Grant consortia. Stennis Space Center could serve as an outreach intermediary to the remote sensing industry as a whole. Professional societies, like ASPRS, AGU, and GSA, can also provide a national overview of workforce needs. NASA and/or Space Grant could create and maintain a Web site and list server dedicated to posting remote sensing job opportunities. Along this same line of thought, a sponsored online journal would serve a number of purposes. Color illustrations in paper-based publications are very expensive and can thus limit one’s ability to illustrate the results of remote sensing and GIS models. A NASA-sponsored peer reviewed online journal would allow for the publication of larger numbers of color illustrations and MPEG movies at little or no cost to the investigator. This would provide university researchers with a forum to reach industries and other universities. Possible topics for papers would include remote sensing and GIS models or the latest applications of remote sensing models to new NASA instrument data sets. The online journal could also provide a forum for industries to post their needs or desired skill sets, or to elicit responses for general problems that they may have to solve.

The conversation between universities and businesses should be moderated at a national level by either a professional society (e.g. ASPRS, AGU, GSA) or by NASA. On the regional level, Earth Grant (Land, Sea, and Space) institutions may be tasked with coordinating ongoing dialog. Professional societies and organizations definitely have a role in this regard although their particular tasks have to be better defined.
**Question 5:** *How do we adjust to changes in technology and platforms vs. persistent underlying principles?*

HDF-EOS is an example of how complicated NASA can make fairly routine operations like the data distribution process. NASA should use standardized data formats for data products.

NASA instrument teams should be charged with certain educational tasks. Through the instrument teams, NASA could provide sample data sets, lesson plans, and application examples in order for the latest NASA data sets and technology to be accessible to the classroom. Proposals could also be entertained to obtain data for educational purposes through NASA data buys.

**Question 6:** *What is the appropriate community college-university relationship?*

The main role of the community colleges is to attract students into more detailed remote sensing and GIS programs available at four-year colleges and universities. Secondary objectives of community colleges are to provide introductory remote sensing and GIS courses and perhaps a remote sensing/GIS associate’s degree.

Space Grant can also provide traineeships to community college students through the fellowship programs offered by individual consortia. Community college students would competitively apply for traineeships that would involve in-depth studies of remote sensing and GIS projects. These projects may be linked to research being done at a local four-year university.

Communication between universities and their associated community colleges should improve by providing announcements of seminars and courses offered. Researchers at universities could regularly provide lectures or seminars at the community colleges to generate interest.

**Question 7:** *What is the role of distance learning in addressing workforce needs?*

Distance learning through the use of Internet technology has an important role in the distribution of ideas and lessons for widely separated community colleges and universities. Distance learning environments can take advantage of unique expertise available at only one location. Distance learning can also be used to provide courses at times or locations that allow those already in the workforce to participate at their leisure. NASA should help to negotiate with software companies to provide remote sensing and GIS software licenses to support on-line courses. Courses should be available for a minimal cost.

**Group 4:** *Focus on new applications and opportunities and on university-industry-agency communications*
1. What are the current anticipated technological developments and what kinds of new applications and workforce opportunities will they produce? Will these significantly change the way we prepare students, and in what way(s)?

We deleted the first question because it focused on applications that can only be thought of by practitioners. Instead, we suggested several persistent technologies and concepts to be applied in future developments. Examples include:

- Earth sciences (physical and cultural geography, natural resources, etc.)
- Critical thinking and problem solving
- Communication skills and technologies
- Introduction to applied physics
- Math skills (statistics, trig, calculus, analytical geometry – development of new course)
- EM spectrum
- Data models (functions and structures)
- Advanced new mathematical concepts (fuzzy math, non-linear mathematics)
- 4-D data models and visualization
- Computer science (programming, networks, hardware-software interface, etc.)

We need to teach students problem-solving, not specific technologies. We need to increase the number of math courses. The fundamentals of remote sensing should include survey courses and field exercises. One option might be to extend a more complex version of the GLOBE program to the college level.

Visual data should be used to motivate students. Knowledge should be connected with need, giving students a reason to pursue certain courses. Students must be exposed to remote sensing early. One novel approach would be to send undergraduate students into elementary schools to explain remote sensing. A representative also should be sent to freshman orientation to talk about remote sensing.

Professional societies need to be introduced during undergraduate programs. Their use to both recruit undergraduates and help guide education for practical applications was one of the working group’s strongest points. Faculty should encourage continuing education and professional development.

2. How can college and university faculty remain informed about remote sensing workforce needs? If a continuing dialog is desirable, who should moderate and advance that conversation? How should it be structured or led? Should it be publication-based (i.e., a newsletter or web publication), organization-based (i.e.,
local university-industry working groups), or might it include increased collaborations via visiting researcher/faculty opportunities in industry, agencies, and universities? Externships?

A number of sources could be developed to serve as conduits for information on workforce needs. The USGS could serve as one vehicle to keep college and university faculty current, possibly through an online newsletter. Another source would be a list server open to industry, government and users. Space Grants could utilize a Web site or list server to act as a clearinghouse for remote sensing news, data, applications, methods, etc. This would require someone at Space Grant to take responsibility for the project, perhaps an Earth science working group. Professional societies and industry trade magazines could also provide information.

Adjunct faculty from industry or research labs should be encouraged. Outreach efforts should also target state coordinating bodies (GIS) and user groups. Public awareness of remote sensing should be fostered through outreach to communities such as science road shows and a frequent update of materials. Advertising and publicity, including university media relations, should be used to communicate applications, capabilities, and opportunities in remote sensing. Human interest stories can be effective, too.

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Appendix A

Presenter Biographies

David S. Bartlett (co-convener) accepted the appointment as associate director of the Institute for the Study of Earth, Oceans, and Space (EOS) at University of New Hampshire in 1989. He previously served as a research scientist at the NASA Langley Research Center conducting studies of the environment using sensors on Earth-orbiting satellites. His research interests there included chemical interactions of vegetation with the atmosphere, causes and effects of global-scale climate change, and management of coastal resources. Dr. Bartlett is responsible for the management of the Institute's research and educational programs and assists the director in planning and developing new avenues for external support of the Institute. He is the founding director of the New Hampshire Space Grant Consortium, an educational and public information collaboration of New Hampshire universities, colleges and science organizations. Dr. Bartlett continues his research in applications of satellite sensors to assess large-scale variation in environmental conditions and the impact of terrestrial ecosystems on global biogeochemical cycles. He serves on the policy advisory committee of the Maine/New Hampshire Sea Grant Program.

Ronald J. Birk is director of the applications division for the Office of Earth Science at NASA. He is responsible for oversight of the Earth science-based national and international applications enabling decision support through federal agencies and partnerships with the academic and private sectors. Ron has 16 years of experience as a key developer of remote sensing systems, data products, data handling systems, and decision support systems. Past experience includes technical management for on-site contractor to the commercial remote sensing program at NASA’s Stennis Space Center through over 100 remote sensing application projects and the development of five airborne remote sensing systems, including the CAMS and ATLAS multispectral scanners. He has experience with applications using high-resolution optical, multispectral, hyperspectral, radar, and lidar data from airborne and space-borne remote sensing systems. He received a bachelor’s degree in physics from the University of Notre Dame in 1982.

Mark Brennan has 18 years experience in developing systems to process spatially related raster and vector data for mapping and charting applications. He joined Space Imaging, based in Thornton, Colo., in July 2000 and currently directs remote sensing solutions for federal government applications. Prior to joining Space Imaging, Mr. Brennan was a principal member of the technical staff at TASC, located in Reading, Mass. While there, he co-founded Emerge, which provides digital airborne imagery for multiple vertical market applications across the country. Prior to TASC, Mr. Brennan was a physical scientist at the Defense Mapping Agency (now part of NIMA) where he developed techniques to support topographical map and nautical chart production using digital multispectral data. Mr. Brennan received his master’s degree in photogrammetry/remote sensing from Purdue University and his master’s degree in renewable natural resources/remote sensing from the University of Connecticut. His
bachelor’s degree in wildlife biology was earned at the University of Massachusetts. He also holds a secret clearance.

Patrick Bresnahan is currently the geographic information officer for Richland County, SC. He is an ASPRS (American Society for Photogrammetry and Remote Sensing) certified mapping scientist in GIS/LIS. He currently co-chairs the technology subcommittee of the South Carolina State Mapping Advisory Committee (SMAC) and participates in the NASA Program Planning & Analysis program. He earned his bachelor’s degree from the University of Maryland-Baltimore County; his master’s degree from Indiana State University; and his doctorate from the University of South Carolina, all in geography. He participated in the postgraduate research program for the U.S. Department of Energy (DOE) and later was awarded a post-doctoral research fellowship sponsored by the Oak Ridge Institute for Science and Education (ORISE). Post-doctoral research was conducted at the DOE facility at the Savannah River site. He also received fellowship awards from AM/FM International (now GITA) and NASA under the South Carolina Space Grant Consortium. He maintains membership in ASPRS, AAG, GITA, and Sigma Xi. He has remained active in those organizations through numerous conference presentations and research publications in photogrammetric engineering and remote sensing.

James Campbell serves on the faculty of the Virginia Tech Department of Geography in Blacksburg, Va. He has held the rank of professor since 1988 and has served as department head since 1993. His text, “Introduction to Remote Sensing,” is widely used for university courses in several disciplines in the United States and Canada. His studies in the field of remote sensing began informally during his undergraduate years at Dartmouth College and continued during his service in the U.S. Army. He was employed by the Remote Sensing Laboratory at the University of Kansas, and later by the Kansas Geological Survey. He has been active in designing interactive Web-based instruction in the interdisciplinary project, Statistical Application in the Social Sciences, and in collaborative work to develop Web-based instruction in image analysis and remote sensing. Dr. Campbell's research has been devoted to several topics within the fields of GIS, remote sensing, image analysis, and analysis of soil variability. He is author or co-author of over 30 articles published in journals in the fields of geography, remote sensing, geology, hydrology, and soil science. In addition to the text mentioned above, he is author of “Mapping the Land: Aerial Imagery for Land Use Mapping” (1983), and co-author (with F. D. Hole) of “Soil Landscape Analysis” (1985). He has held offices at both local and national levels in the American Society for Photogrammetry and Remote Sensing and received the Society’s Outstanding Service Award in 1994 and their Fellow Award in 1996. In 1997, he received the Outstanding Service Medal awarded by the remote sensing specialty group of the Association of American Geographers.

Daniel L. Civco is the director of the Laboratory for Earth Resources Information Systems and associate professor of natural resources management and engineering at the University of Connecticut. He earned his doctorate in remote sensing in 1987. His research focuses on using remote sensing in land characterization, resource management, and land use applications. Dr. Civco is the author of numerous publications based on the
Janice DeCosmo (co-convener) is assistant dean of undergraduate education at the University of Washington and the director of the Washington NASA Space Grant Consortium. She earned a doctorate in Atmospheric Sciences in 1991 specializing in atmosphere-ocean interaction and is currently an affiliate faculty member in the UW Department of Earth and Space Sciences. Her research interests include marine boundary layer turbulence, mid-latitude storm development and climate change. Her publications include technical papers on experimental methods in marine boundary layer studies, the effects of sea spray on the marine environment, and using technology in science teaching. She has taught science at all grade levels from kindergarten through graduate school, and more recently has focused on helping university faculty find ways to include undergraduates in their research and to integrate research into their teaching.

John Dwyer is a principal scientist with Raytheon ITSS at the U.S. Geological Survey (USGS) EROS Data Center (EDC). He has a bachelor’s degree in geology from St. Lawrence University and master’s degree in geological sciences from the University of Colorado. Mr. Dwyer has more than 20 years of experience in the application of remote sensing and GIS technology towards natural resource assessment and studies of landscape change. He served as department manager of satellite systems engineering and development for Raytheon ITSS at EDC from 1995 to 2000. Mr. Dwyer is currently the project scientist for the Land Processes Distributed Active Archive Center (DAAC) in support of NASA’s Earth Observing System program.

Luke Flynn received a Bachelor of Arts degree in physics from Cornell University followed by a Doctor of Philosophy degree in geology and geophysics from the University of Hawaii at Manoa. He is currently an associate researcher at the University of Hawaii and is the Hawaii Space Grant Consortium interim director. His research specialties are remote sensing instrumentation and applications. He has been a member of the Landsat 7 and Earth Observing –1 Science Teams. His scientific interests include studies of active volcanic eruptions and forest fires. He is currently working on developing university-government-industry partnerships to facilitate the creation of a master’s degree apprenticeship program at the University of Hawaii that would highlight NASA technology and applications for training the workforce.

Michael F. Goodchild is a professor of geography at the University of California, Santa Barbara; chair of the executive committee of the National Center for Geographic Information and Analysis (NCGIA); associate director of the Alexandria Digital Library Project; and director of NCGIA’s Center for Spatially Integrated Social Science. He received his bachelor’s degree in physics from Cambridge University in 1965 and his doctorate in geography from McMaster University in 1969. After 19 years at the
University of Western Ontario, including three years as chair, he moved to Santa Barbara in 1988. He was director of NCGIA from 1991 to 1997. He was elected member of the National Academy of Sciences and foreign fellow of the Royal Society of Canada in 2002. In 1990, he was given the Canadian Association of Geographers Award for Scholarly Distinction; in 1996, the Association of American Geographers Award for Outstanding Scholarship; in 1999, the Canadian Cartographic Association’s Award of Distinction for Exceptional Contributions to Cartography; and in 2002, the Educator of the Year Award from the University Consortium for Geographic Information Science. In 2001, he received a Lifetime Achievement Award from Environmental Systems Research Institute, Inc. He has won the American Society of Photogrammetry and Remote Sensing Intergraph Award and twice won the Horwood Critique Prize of the Urban and Regional Information Systems Association. He was editor of Geographical Analysis between 1987 and 1990, and serves on the editorial boards of ten other journals and book series. In 2000, he was appointed editor of the Methods, Models, and Geographic Information Sciences section of the Annals of the Association of American Geographers. His current research interests center on geographic information science, spatial analysis, the future of the library, and uncertainty in geographic data.

Pamela Lawhead is director of the Center for Geospatial Workforce Development and associate professor of computer and information science at the University of Mississippi. The Center’s mission is to develop a repository of dynamic online coursework in the field of geospatial information technology in order to enhance the traditional university learning environment. This coursework will be delivered via various media including the Internet, CD-ROM, DVD and compressed video. This translates into anywhere, anytime delivery of educational material in an interactive, learner-centered, multi-modal environment. Dr. Lawhead is an active researcher in software engineering and programming. She has distinguished herself as a gifted and dedicated teacher, having taught programming to people from ages 9 to 80 in her roles as a university professor, director of Ole Miss Computer Camp and teacher of a leisure course to senior citizens.

Berrien Moore III, professor of systems research, has been the director of the Institute for the Study of Earth, Oceans, and Space at University of New Hampshire since 1987. In 1993, he received the University’s first Excellence in Research Award and was named one of UNH’s first Distinguished Professors in 1997. Professor Moore was appointed in 1987 to chair NASA’s senior science advisory panel and upon completion of his chairmanship he received NASA’s highest civilian award, the NASA Distinguished Public Service Medal for his outstanding service to the agency. Actively involved on panels and committees at the National Academy of Science, he ended his chairmanship of the National Academy’s Committee on Global Change Research with the publication of “Global Environmental Change: Research Pathways for the Next Decade” in 1999. From January 1998 to January 2002, he served as chair of the Scientific Committee of the International Geosphere-Biosphere Programme (IGBP) and as a lead author within the Intergovernmental Panel on Climate Change’s (IPCC) Third Assessment Report (TAR), released in Spring 2001. In July 2001, he chaired the Global Change Open Science Conference in Amsterdam and is one of the four architects of the Amsterdam Declaration on Global Change.
Appendix B
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