DLESE

A Community Plan

Cathryn A. Manduca
David W. Mogk
June, 2000

Digital Library for Earth System Education

Final Report from the
University of Oklahoma to the
National Science Foundation
Grant 99-06648

Setting: Faculty Lounge in a University that is not far, far away. Brad looked at Felicia skeptically, "You want me to teach a section on global climate change that is exciting, relevant, and incorporates learning about the scientific method. Starting next term? That's a pretty tall order!"

Felicia, the science Chair and ever the optimist, replied, "I suppose. Let's check out that new Digital Library for Earth System Education. We should be able to find some interesting class activities there."

Sitting down at a nearby PC, the pair of geology professors quickly moved to the Digital Library's discovery system. Using the map interface, they zoomed into a hundred mile region around their campus, and set the topic index to global climate change. Topping the list that the search engine returned was a climate record from Lake Mendota going back in geologic time, indicating warm periods when the Earth's poles were not topped by ice caps.

"Hey," Felicia called out, "we can use the past history of Lake Mendota to think about what might happen in the future. We'll have the students look at past climate and CO_2 levels to predict what might happen in future climates."

"Wow, that's sure going to be a challenge," Brad replied. "How are we ever going to get the students to gain an understanding of large-scale global processes, and then relate these to an understanding of how climate has varied over time in one location?" Brad clicked one more link. "No, wait, here's something that might help. It's a tutorial for faculty about helping students understand processes on geological time scales. Look, there's some guy here who studies how people develop their understanding of time as his research topic, and there are some really practical suggestions for helping students get past their problems with 'deep time.'"

Consider the possibilities

Going back to the DL search engine, Felicia again asks for the global warming theme, but this time asks for predictions. "OK. I'm beginning to see a way to make this work. Say we start with the changes in global atmospheric carbon dioxide levels as indicated at Mauna Loa. Then we do the same for local recording stations. This establishes the primary observational evidence for global warming. Then we'll move on to the Lake Mendota data to study past eras of increased greenhouse effect warming. Finally, we bring it back to the present by having groups of students do modeling using these scaled-down versions of the IPCC models, looking at both global and regional effects. This should be a pretty substantial project."

"Well, we could have the students work in small groups covering different parts of the project, and then have the groups report their findings in a campus-wide colloquium on global change." Brad's enthusiasm was growing as he considered the prospect of an active classroom where students would take greater responsibility for their own learning. And he realized that he could personally learn a lot about an important subject along with his students.

"Well, I'm glad you're beginning to see the possibilities. Remember when you're up for tenure review this will look awfully good. These activities and curricula you're developing can be registered in the Digital Library and count as journal publications in your review."

—Modified from Panel 3, Portal to the Future Workshop

Executive Summary

Earth system education is entering an exciting and challenging new era as significant changes are being made in the ways teachers teach and students learn about the Earth. The Earth system approach provides new insights into the interfaces and connections between the many components of the Earth system. Instructional activities are increasingly focused on inquiry- and discovery-based learning. There is a growing awareness of the need to integrate "best" instructional practices with accurate and reliable scientific content. At the same time, new information technologies provide direct linkages between people (e.g., educators, researchers, and the community at large) and information about the earth (e.g., instructional materials, data sets, images) that make new ways of learning possible. The Earth system education community has responded to these new opportunities by calling for development of a facility that:

- is interdisciplinary in nature;
- allows students and educators to rapidly find resources they need;
- provides the training and tools needed to effectively use these materials; and
- enables students to explore Earth data.

The Digital Library for Earth System Education (DLESE) has been conceived, and is being constructed, to meet these multiple needs in support of Earth system education. DLESE can have a major impact in implementing the National Science Education Standards in the K-12 system; enhancing undergraduate science education for future scientists, future teachers, and all students; and increasing the resources available for all citizens and policy makers to learn about the Earth. Digital technology makes it possible to imagine new methods for engaging the broad diversity of learners more effectively. We have an unprecedented opportunity to make major advances in the scientific literacy of our population in all venues.

The Vision

The first step in building DLESE is to create a shared community vision. Such a vision was developed at a topical workshop, Portal to the Future: A Digital Library for Earth System Education, and refined with input from sessions at professional society meetings, and solicited and volunteered contributions from individuals.

DLESE is conceived as an information system dedicated to the collection, enhancement, and distribution of materials that facilitate learning about the Earth system at all educational levels. The form and function of DLESE are defined by its unique focus on Earth system education. DLESE will support Earth system education along numerous dimensions:

- in the development of **collections** of high-quality materials for instruction at all levels and covering all components of the Earth system;
- by providing access to **Earth data sets** and imagery, including the tools and interfaces that will enable their effective use;
- through the development of **discovery and distribution systems** to efficiently find and use materials encompassed by the DLESE network;
- by providing support **services** to help users most effectively create and use materials in the DLESE "holdings"; and
- through new **communication networks** to facilitate interactions and collaborations across all interests of Earth system education.

These diverse yet complementary functions must be integrated and coordinated for greatest impact. Thus, DLESE must be a **community center**—a single place where people can go to find information, learn new skills, and make new contacts. Ultimately, DLESE should be the resource of first choice for anyone interested in learning more about the Earth.

Building the Library

DLESE will be a distributed network built as a community effort. Collections, services, and tools will be developed and maintained by numerous partners rather than being housed in a single centralized facility. Fundamental to the design and construction effort is a commitment to building a library that responds to the needs of the Earth system education community. An active outreach effort will work to engage the broadest possible participation from the Earth system education, library, digital library, and information technology communities in DLESE. This community will be involved in all aspects of design, construction, and testing of the library. Assessment of the library effort and feedback from the community are essential tools in creating a useful and used facility.

Construction of the library as a federated effort is now underway. To coordinate the DLESE effort and integrate the library into a seamless and complete whole, a governance structure and central program office have been established. A Steering Committee, supported by several standing committees, will guide DLESE. The Steering Committee, elected in November 1999, has focused on developing the policies needed for community-wide cooperation and coordinating the initial community submission of proposals to construct the library. It is also engaged in developing plans for long-term sustainability and intellectual property policies for DLESE. The standing committees are working with the community to address the topics of user needs, services, collections, and technology issues.

The DLESE Program Center (DPC), located at the University Corporation for Atmospheric Research, is engaged in both the community and technical aspects of library construction and management, and is constructing the core technical infrastructure needed for the integrated effort. The DPC has begun to design and prototype the essential components of DLESE: the discovery system, the collections, and user services. An important aspect of this work is a design process that translates descriptions of anticipated use as articulated in user scenarios into system requirements using an iterative discussion between DLESE users and DPC staff. Prototypes implementing the system requirements are then tested in the community and revised to meet recognized user needs. Efforts to date have focused on:

- a graphical user interface that allows users to interact with the system;
- an underlying system architecture that connects the user interface to a search engine, resource database, and other supporting services;
- a testbed database and resource collection;
- cataloging practices (i.e., metadata schema) that describe resources in the data base and enable searching according to user-specified attributes; and
- protocols that allow the discovery system to access information about resources at distributed sites (i.e., interoperability requirements).

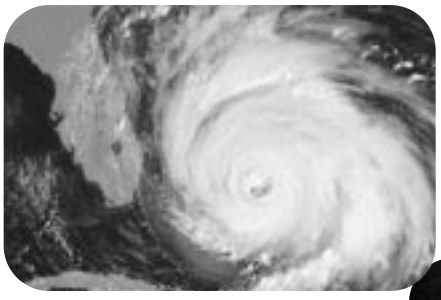
Earth system educators have developed a strong consensus that DLESE will be most effective if it is an integral part of the larger network of digital libraries. In particular, DLESE shares many goals with the National SMETE Digital Library. Given the integrative nature of learning about the Earth, educators and students will benefit extensively from the ability to draw resources from this larger collection to support their work. At the same time, the Earth sciences offer a knowledge base, skills, and philosophical approaches to problem-solving that complement those of sister disciplines. Connections to libraries supporting scientific research are a natural extension of DLESE, as these linkages will add value to both the educational and research enterprises.

In the past year, DLESE has become a large community effort. Yet the most exciting work lies ahead: transforming dreams into a working facility, filling it with the best resources the Earth sciences have to offer, and using DLESE to truly transform learning about the Earth. The goal of this report is to enable this greater task by setting forth the need, the vision, the plan, and the progress to date. With this information, the stage is set for broad participation in all aspects of DLESE. DLESE was established from a community vision—we invite all who are interested to help make this vision a reality.

Table of Contents

DLESE should be provocative and engaging, a place where those interested in asking questions about the Earth system will go. One could think of it as a mall that would appeal to a variety of shoppers; it would have exciting displays of material to promote inquiry, a wide selection of products and product venders, and kiosks for discussions about hot topics.

Panel 1, Portal to the Future Workshop



A Living Institution, libraries contain the heritage of humanity: the record of its triumphs and failures, its intellectual, scientific, and artistic achievements, and its collective memory...They provide tools for learning, understanding, and progress. They are the wellspring of action, a laboratory of human aspiration, a window to the future...they are a medium of progress, autonomy, empowerment, independence, and self-determination...the symbol of our universal community, of the unity of all knowledge, of the commonwealth of learning... It represents embodies the spirit of humanity in all ages. *Vartan Gregorian, President, Carnegie Corporation, 1998 Annual Report*

The Challenge

"By 2005, to design and implement the Portal, a digital library for Earth science education that serves educators and students by facilitating a new era of sharing of materials, and by being the reservoir of choice for those materials."

—Michael Goodchild, University of California Santa Barbara, opening address, Portal to the Future Workshop

Imagine an interdisciplinary educational resource that allows you to rapidly discover the instructional materials you need; connects you to real-time or archived Earth databases; delivers resources in a format that can readily be used in your classroom; and includes the training you need to use these materials.

The Digital Library for Earth System Education, DLESE, will provide a dynamic environment in which tested "best practices" in instruction, new advances in understanding the Earth system, and emerging new information technologies will be integrated in support of Earth system education. DLESE will support Earth system education at all levels and in all settings: teachers and faculty in schools, colleges and universities; students in traditional classrooms, and those learning at home, in the field, or at a distance; and citizens learning on the web, in museums, or informal classes. By employing new educational technologies (NSF 98-82), DLESE can fundamentally change the way students learn, instructors teach, and researchers interact.

> [T]he concept of a digital library is not merely equivalent to a digitized collection with information management tools. It is rather an environment to bring together collections, services, and people in support of the full life cycle of creation, dissemination, use, and preservation of data, information, and knowledge. *Report of the Santa Fe Planning Workshop on Distributed Knowledge Work Environments: Digital Libraries (1997)*

DLESE will be an organic entity that responds to the needs of the Earth system education community while adapting to new advances in information technologies. DLESE will grow from the community by engaging users who teach and learn about the Earth in the development and evaluation of the library. Community-based ownership and management will ensure that DLESE is a useful and used facility. In the same way that the Earth system approach provides unifying principles for understanding interactions among the many components of the Earth system, DLESE will integrate the delivery of high-quality instructional materials, training, communication networks, and related services in support of Earth system education.

The library as an institution has traditionally been a community resource. It is more than an archive of materials—organizing the corpus of human knowledge and creativity, disseminating information through a strong tradition of open and fair access, and serving as a meeting place for community activities. The digital library builds on the rich heritage of traditional libraries and adds dynamic dimensions that were heretofore unimaginable (e.g., NSF 99-112):

- instantaneous, global distribution of information according to specific user needs;
- organization of information to allow effective access from numerous points of entry;
- access to real-time and archived data sets and the ability to render this information in ways useful and meaningful to the widest range of users; and
- creation of new, virtual communities of scholars.

This report serves multiple purposes. First, it summarizes the need for the library as articulated by those who teach about the Earth in a wide variety of settings. Second, it presents a vision for the library—what the Earth system education community would like the library to do and why. In both sections, we try to articulate the specific improvements that educators believe can be catalyzed or implemented using DLESE. Lastly, strategies and plans for library building are laid out and progress to date is summarized. The report is based on input collected from the Earth science community through a topical workshop, Portals to the Future: A Digital Library for Earth System Education, through a series of "town meetings" and theme sessions at meetings of professional societies, through solicited and volunteered contributions from the community at large, and through experience gained during the first year of DLESE activities, including initial work on a system prototype. These activities are described in more detail in Appendix 1. The recommendations of the panel reports from the Portal to the Future workshop, the record of activities to date, and opportunities to contribute to the DLESE effort can be found at the DLESE website: www.dlese.org.

Many times teachers complain about the lack of time or lack of resources necessary to make changes. I, for one, fall into that category. No one needs to remind me that field trips are good or that I should do more technology applications with my class, but the logistics (large class size), time, and money constraints make them easy to dismiss. The digital library proposed by DLESE is an innovative way to cut through these constraints. I have the technology, and I know what to do; I just need to do it. I need the support and the resources to update the things I already do with my students. One of the ways I think I would use the DLESE library is to find the new and innovative topics in Earth science education. I would like to explore the Earth system approach and compare it to what I do currently. I'd like to enhance all that I do and make it better. I would like to download images, maybe that show a physical feature or structure to use in a lesson. I would like to use online exercises that students can complete in order to supplement the classroom instruction. An on-line field experience could never replace actually being there, but it is far better than the alternative of not doing anything. I am positive that the uses I listed above barely scratch the surface of the potential of this library. This is a resource whose time has come. We do not have any more excuses. We need to move ahead.

—Jane Brandt, Willow Creek Middle School, Rochester, Minnesota

This is a resource whose time has come.

You want your students to be more engaged in Earth System sciences and become more aware of the impact of the environmental decisions that affect their locality, region and planet. Are you aware of all the teacher's programs that are available in your area and can support your interest and effort? Are you aware of how you can bring real-life research experiences into your classroom?

With DLESE portals to information, you can find out what professional development programs are available to you, and how you can participate in them. DLESE can facilitate your participation and your students' involvement in exploring the ocean floor or other planets. DLESE can provide you with software and web tools to communicate with scientists engaged in expeditions, and allow you to follow day by day the evolution of such expeditions. And imagine through DLESE, you could even forge collaborations with classes and instructors in other states or countries that are also following the expedition. Supported by DLESE, you and your class become part of the educator-researcher-learner community that integrates technology, math, physics, biology, geology or an Earth system approach to teaching.

—Submitted by: Veronique Robigou, School of Oceanography, University of Washington

The Need is Immediate, The Time Is Now

We are at a unique point in Earth system education. A digital library has become technically possible at the same time Earth system education is undergoing rapid change and responding to new opportunities. The need for knowledge of the Earth system

in local and global decision-making has never been greater. Research has demonstrated the importance of understanding the Earth as a set of interacting components that make up a single system. Earth system education is implementing new materials to bring this understanding to students at all levels with content that makes the study of the Earth relevant, meaningful, and important. Increasingly, students are using new technology to explore Earth data and to experience first hand the excitement of scientific discovery. The delivery of educational resources and the communication networks possible with a digital library can facilitate major advances in all of these areas.

The concept of DLESE has emerged from:

- the public's demand for improved science, mathematics, engineering and technology (SME&T) education at all levels;
- the need for instructors and students to have access to high-quality educational materials that are presently difficult to find and utilize;
- the need for specific training for instructors and students to effectively use scientific information, methods and tools;
- the value added to the research enterprise by translating new discoveries, information, data sets, and images about the Earth into effective instructional activities; and
- the public's need for access to reliable information about the Earth to inform personal and societal decisions.

Educators at all levels have repeatedly called for an information system that can efficiently deliver high-quality educational materials in formats that are readily accessible, with a high degree of confidence that the materials will be useful, interesting, and effective (NSF 96-139; AGU, 1997). There is a concomitant need for continuing professional development for all educators to upgrade their knowledge base, to employ new materials, and to master new methods or skills. Given the rapidly evolving state of scientific discovery, educators must be able to interact with colleagues within a field of expertise and to make connections to professionals in related disciplines. Simultaneously, the national priority to help students at all levels acquire "scientific habits of mind" (e.g., AAAS, 1989) requires new tools for accessing and exploring data.

Taking advantage of new information technologies, DLESE can enhance the collection, distribution, and service functions of a traditional library. Serving as a community center for Earth system education at all levels, DLESE creates the possibility of a seamless, lifelong learning experience. DLESE is needed to respond to community needs, address the national agenda to improve SME&T education, and realize new opportunities afforded by information and educational technologies.

A New Place in K-12 Education

The National Science Education Standards (NSES; NRC, 1996) emphasize a new priority for increased student understanding of Earth and space science. The NSES content standards are firmly rooted in the Earth system science approach. These national standards are serving as the foundation for the development of state and local science education standards across the nation. Successful implementation of the NSES will require concerted effort by all science educators. Among the resources required to continue implementation of the standards are:

- new materials for students and teachers;
- assessments of materials and student learning;
- better communication between K-12 and undergraduate educational communities; and
- new curricula to train both in-service and pre-service teachers.

DLESE can play a central role by providing an integrated gateway to information, materials, networks, and training needed for national implementation of quality Earth and space science education in the K-12 arena.

share the goals of science education

Imagine a school district attempting to improve science education. The district has adopted a curriculum that is aligned to the National Science Education Standards and it embraces the philosophy presented in Science for All Americans by de-emphasizing specific content vocabulary and emphasizing the unifying themes and concepts. The standards describe professional development for science teachers and science content standards. As Earth science content increases and changes, DLESE supports a teacher's understanding in science and allows them to keep pace. DLESE has created collaborative learning environments in which Earth science content experts are linked with the experience and current needs of teachers. DLESE provides a rich environment for teachers to access resource material for problem-based learning activities. To reduce the amount of time involved creating Earth science lesson plans, DLESE's context matrix graphically interfaces Earth science information to specific standards. For in-service chemistry and biology teachers—often called upon to teach Earth science in the district's high schools—DLESE implements a constructivist model designed to integrate Earth science ideas into existing conceptual frameworks. Environmental issues, such as greenhouse gases and ozone depletion, are used to engage chemistry teachers. Paleontology is a natural starting point for biology teachers; this leads to an understanding of Earth systems and the role of global change in the evolution of life. DLESE provides frameworks for teaching science process. Using satellite images and remote-sensing data, teachers conduct inquiry-based activities that develop problem-solving and analytical skills. DLESE and the school district share the goals of science education—to teach basic conceptual knowledge, construct an understanding of the nature and process of science, and develop habits of mind that will enhance the ability of individuals to function in a complex society.

—Ray Thomas, Department of Geology, University of Florida

Suppose for a moment that you are teaching an introductory Earth science class at a small community college in an isolated rural area. You have just started requiring research-oriented projects in your introductory course and have been helping students with resources across a wide spectrum of Earth science topics. One group of students is working on tree ring cores they have acquired from a local lumber company and are trying to tie the tree ring data to past precipitation. You are a "one-person" department, your background is in igneous geochemistry and you have no prior experience or course work in paleoclimatology. If you were in a large department you might be able to walk down the hall and seek help from a colleague. Your small geoscience collection in the library offers little help and wading through the numerous resources of the WWW seems daunting, with much of the material not appropriate for your specific needs in this project.

DLESE, the Digital Library for Earth System Education, offers you the opportunity to quickly "get up to speed" in the general concepts of paleoclimatology and the specific use of tree ring data as a climate "proxy." It not only offers appropriate overviews for you as an instructor but also a guide to on-line resources for your students. You will be able to find potential project ideas used at other colleges and links to digital archives such as the digital tree ring database maintained by the University of Arizona. In addition, DLESE will link you to faculty who are similarly engaging introductory students in research projects through on-line discussion groups.

—Chris Di Leonardo, Foothill-DeAnza Community College

A New Emphasis on Science Education for All Undergraduate Students

"All students should have access to supportive, excellent programs in SME&T, and all students should acquire literacy in these subjects by direct experience with the methods and processes of inquiry."

—Shaping the Future (NSF 96-139)

Improved undergraduate SME&T education for all students is now a national priority. Fundamental to this reform is the recognition that more emphasis should be placed on students experiencing the process of science, in addition to mastery of fundamental scientific principles and content. Equally important is a new recognition of the diversity of learning styles that students bring to the classroom and the need for all students to construct their understanding of science from experience rather than through rote memorization. These changes require new materials and new training for educators. The need for a central digital educational facility to assist with these changes is well recognized (NSF 96-139; NSF 99-112).

> Together with other major players (such as the NRC, AAAS, ERIC, and the National Library of Medicine), explore the establishment of a national electronic system for validating and disseminating successful educational practices...
>
> Provide specific training sessions for faculty across institutions, in topics such as how to do inquiry and collaborative learning in large 'lecture' classes, how to assess learning outcomes, and how to document learning gains at the departmental and institutional levels.
>
> *—Recommendations from Shaping the Future (NSF 96-139)*

The Earth sciences play a very important role in this new mission for undergraduate science education. Not only have they traditionally enrolled a large fraction of students fulfilling science distribution requirements, but the Earth sciences provide an excellent vehicle for teaching science in ways that are accessible, relevant, and meaningful.

> The interdisciplinary nature of Earth system science at all levels provides an unusual opportunity for developers of curriculum materials to introduce significant and relevant applications of physics, mathematics, chemistry, biology, and technology. Interdisciplinary applications enhance students' communication and interpersonal skills and their quantitative, analytical, and problem-solving abilities. Earth system science education also provides an excellent opportunity to consider the broader interrelationships among the natural and social sciences, humanities, and arts. Our understanding of the Earth system is formed by inquiry that extends beyond specialized scientific disciplines to a larger human experience. It provides a framework to explore personal and societal values in relation to the Earth. Earth system science examines the interconnections between the Earth systems and human existence through time and space, from societal levels to the individual and from global to local scales. Such knowledge is necessary for humans to make informed political, economic, and social decisions as citizens.
>
> *—Panel 2, Shaping the Future of Undergraduate Earth Science Education (AGU, 1997)*

The new social and technical structures afforded by DLESE present a formidable combination to fundamentally change the landscape of undergraduate SME&T education. The materials, methods, and tools that will become available through DLESE will impact not only what students learn but how they learn.

Earth Science for All Citizens

"While acknowledging the continuing need for science and engineering in national security, health, and the economy, the challenges we face today cause us to propose that the scientific and engineering enterprise ought to move towards center stage in a fourth role: that of helping society make good decisions. We believe this role for science will take on increasing importance, particularly as we face difficult decisions related to the environment."

—Unlocking Our Future—Toward a New National Science Policy House Committee on Science, 1999

There has never been a greater need to deliver relevant and meaningful information about the Earth to interested citizens, particularly regarding topical issues related to natural hazards and resource utilization (e.g., USGS, 1999). Community planners, the business sector, parents, and citizens-at-large have compelling reasons to learn more about the Earth, and the Earth science community has a responsibility to respond to public requests for information in ways that are accessible and understandable. We must share our understanding of the Earth system to contribute to the public discourse about policy, as this information is fundamental to safeguarding the health, safety, and financial security of society at large.

> No science offers the opportunity of discovery like the geosciences... We now have a generation of adults ignorant of science and frightened by the technological revolution taking place. In an ever-more competitive world, we cannot afford to lose a second generation. *Bob Ryan, Washington DC weathercaster and former president of the American Meteorological Society*

DLESE will play a central role in collecting, organizing, and distributing information about the Earth to all interested users. Tremendous value will be added to the public investment in data collection and research as the results are used broadly in service to society. One can envision new types of scientific communications that are created to interpret scientific findings to an interested citizenry, or which develop educational materials that simulate or replicate the methodologies, processes, and discoveries of new scientific contributions as reported through traditional scholarly reports. The combination of access to data and to the tools required to interpret and apply these data will assist citizens and policy makers in the process of making informed decisions. Science itself will benefit when greater access is provided to diverse minds to contemplate and interpret the Earth system in entirely new ways.

The Earth System Education Community is Ready

A digital library has the potential to transform education. However, this transformation will not happen without a community that is ready to harness the power of the library and use it to change the way it does business. The challenge is to collectively enable the most effective learning about the Earth, while recognizing a great diversity of learning goals, learning styles, and learning environments. The Earth system education community is ready for this task as DLESE builds on substantial community wide efforts that have taken place in the past decade.

- infuse the Earth system approach into existing courses in the Earth and space sciences;
- new Earth system science courses and curricula must implement best teaching practices to educate all constituencies;
- the Earth and space science community must change its academic culture to actively support reform of science education;
- fully implement the recommendations from Shaping the Future (NSF 96-139), From Analysis to Action (NRC, 1996), and the National Science Education Standards (NRC, 1996).

This vision of an integrated, coherent Earth system approach has already had an impact on departments, curricula, courses, instructors, and students (e.g., AGU theme session, 1999 Fall Meeting). The call for the development and dissemination of better instructional materials, and the need for training for instructors, assessment of instructional materials, more effective use of educational technologies, and establishment of rewards structures for creative contributions to education, are all community-wide concerns. The development of DLESE, and implementation of its collections, services, and communication networks, will provide the tools needed to accelerate the rate of change and expand its impact to all parts of the education community.

> The landscape of undergraduate geoscience education has changed in significant and interesting ways over the past ten years. Classrooms feel different. Faculty spend more time thinking about pedagogy. More professional societies have become involved in geoscience education. Courses and curricula have expanded with interdisciplinary and global approaches to studying the Earth. Technology has transformed student access to information... Involvement and interest in geoscience education issues has risen dramatically in the geoscience community as a whole. *Barbara Tewksbury, Hamilton College, Project Kaleidoscope Featured Essay, 1999*

Two national conferences have drawn together educators from the full breadth of undergraduate geoscience education to evaluate and plan for the future. The first meeting, Scrutiny of Undergraduate Geoscience (AGU, 1994), identified issues of concern to geoscience educators including curriculum content, materials, and pedagogy. The second workshop in 1996 produced a new vision for undergraduate Earth system education, Shaping the Future of Undergraduate Earth Science Education-Innovation and Change Using an Earth System Approach (AGU, 1997). Four major recommendations were made:

Technology is Ready

"This is an experiment in application of known technologies in the context of social issues & limited resources/timeline."
-Gary Horton, DPC System Engineer

> Collectively, these technologies have the ability to provide access to world-wide resources; facilitate the accumulation and presentation of data; and enable communication, interaction, and collaboration among students and instructors to improve the practice of teaching and the experience of learning. *Information Technology, Its Impacts on Undergraduate Education in SME&T (NSF 98-82)*

The idea of a system that organizes information and integrates services is not new, dating back at least as far as Vannevar Bush's vision of the Memex (Bush, 1945). Nor is it a large step from this idea to its application to science education. However, the essential element today is the availability of technology that makes it possible to move forward expeditiously with the development of this vision. It is now possible to effectively collect, evaluate, and organize instructional materials and to deliver these materials over the WWW in a user specific manner. One need only look at the recent explosion of commodities and services offered by e-commerce companies to recognize what we could achieve by implementing existing technology in the service of Earth system education. The technologies needed to build DLESE are becoming widely available and the costs are ever-decreasing. The challenge now lies in integrating this technology into a cohesive, functional, useful library.

The development of DLESE will make fundamental contributions to the advancement of information technologies. DLESE can serve as a testbed where techniques and tools developed in research such as that funded by the National Science Foundation (NSF) Directorate for Computer and Information Sciences & Engineering (CISE) are implemented and serve as a jumping off point for future research. In turn, the specific needs of Earth system education will lead to new research problems with broad application.

Leadership of the Federal Science Agencies

National interest in technology and education currently provides an environment in which federal agencies can support the development of large digital libraries, including one with a focus on SME&T education. DLESE must be an integral part of these larger efforts and support their goals for widespread science literacy. Building on a long history of support for SME&T education and Earth system education, new programs and partnerships within the federal science agencies make development of DLESE an exciting and viable opportunity at this time.

NSF has taken a leadership role in supporting the Digital Libraries Initiative, a national priority that is integrating the efforts of numerous federal agencies. NSF/CISE administers the Digital Libraries Phase 2 Program (NSF 98-63) and the Division of Undergraduate Education (DUE) has responsibility for the National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL; NSF 00-44).

Among the guiding principles for the NSDL are that it:

- be driven by educational and scientific needs;
- facilitate educational innovations;
- be stable, reliable, and permanent;
- be accessible to all (though not all materials will be free);
- build on and leverage past and current work in courseware libraries, digital library research and successful commercial sites;
- be adaptable to new technologies.

—NSF 99-112 Report of the NSF SMETE Library Workshop

> To meet these needs, the workshop articulated a vision of a new type of library, the SMETE Library. This is envisaged as a comprehensive library of the digital resources and services that are available for undergraduate education in science, mathematics, engineering, and technology. The key word here is comprehensive . Faculty are very specific in wanting a single place where they and their students can discover, use, and possibly contribute a wide range of materials. *Report of the NSF SMETE Library Workshop (NSF 99-112)*

The general outlines of the architecture, collections, services, and types of resources for a national digital library for science, mathematics, engineering, and technology education have been described by Wattenberg (1998), and a preliminary vision of a digital library for the Earth sciences was presented by Mogk and Zia (1997).

Construction of DLESE is a natural extension of the long-term support for Earth system education provided through the Directorates for Education and Human Resources (EHR) and for the Geosciences (GEO; NSF 97-171). Both GEO and EHR have independently funded premier educational projects that will provide the core of high-quality library holdings in DLESE. Future projects funded through NSF education programs will be encouraged to disseminate their outcomes through the DLESE communication networks. In addition, The National Aeronautics and Space Administration (NASA) has made important contributions through its Earth Science Enterprise and planetary science programs. In concert with NSF, NASA has a strong commitment to the development of Digital Earth, an integrated, digital Earth data delivery system, which will be an essential part of the DLESE effort. This project builds on existing collaborations among GEO, DUE, and NASA's Earth Science Enterprise.

A Unique Opportunity

The opportunities for major advances in any field require that the needed resources become available at a time when the community is ready to advance. Today we have such a concurrence in Earth system education. It is possible politically, economically and technically to build a digital library that will disseminate needed resources, provide the means for students to explore Earth data, and facilitate communication among the disparate parts of the Earth system education community. What makes this opportunity remarkable, is the strong, united voice from this community asking for this resource. Earth system education is poised to take advantage of DLESE to make major advances in the scientific literacy of our population in all venues. Such a change will have a substantial impact on the public view of the relationship of humans to the Earth. This is indeed a unique time and a unique opportunity.

> Advances in information technology dovetail with progress in the final area I would like to highlight: science literacy. Now being developed, the digital library will provide instructional materials, connect teachers with others who teach similar courses, and provide students with real-time data and information. The teaching resources will be peer-reviewed. We re excited that Earth science can offer some of the most dynamic, real-world, visual data at all levels of learning.
>
> *Rita Colwell, Director, NSF, Complexity and Connectivity: A New Cartography for Science and Engineering, Keynote Speech, Fall 1999 AGU Meeting*

The DLESE Vision

The first step in creating the library is developing a community vision of the desired outcome. DLESE is conceived as an information system dedicated to the collection, enhancement, and distribution of materials that facilitate learning about the Earth system at all educational levels. The form and function of DLESE are defined by its unique focus on Earth system education. To implement this mission, DLESE will support Earth system education along numerous dimensions:

- in the development of **collections** of high-quality materials for instruction at all levels and covering all components of the Earth system;
- by providing access to **Earth data sets and imagery,** including the tools and interfaces that will enable their effective use;
- through the development of **discovery and distribution systems** that will allow all users to define and pursue their personal interests, and to efficiently find and use materials encompassed by the DLESE network;
- by providing support **services** to help users most effectively create and use materials in the DLESE "holdings"; and
- through new **comunication networks** to facilitate interactions and collaborations across all interests of Earth system education.

These diverse yet complementary functions must be integrated and coordinated for greatest impact. Thus, DLESE must be a **community center**—a single place where people can go to find information, learn new skills, and make new contacts. Ultimately, DLESE should be the resource of first choice for anyone interested in learning more about the Earth.

A Community Center

DLESE will serve as the intellectual commons for the global Earth system education community. DLESE will be the primary point of contact for students, educators, and citizens who seek access to reliable information about the Earth and the best methods to promote learning about the Earth. The need for such a center providing a focal point for a community of learners and educators focused on improving understanding of the Earth system was clearly articulated in the recommendations of the Shaping the Future of Undergraduate Earth Science Education (AGU, 1997):

> "Develop a coherent, sustainable, and open consortium, linking the educational missions of K-12, undergraduate, graduate, and informal science communities. All participants in the consortium should share in and reinforce common efforts in faculty development, curriculum development, and dissemination."
>
> *—Joint recommendation of Panels 5 and 7*

DLESE will establish new communication networks between different segments of the community—educators, learners, technologists, and researchers. The library can facilitate communication between new users and experienced users of library materials, between the creators and users of materials, and between learners, educators and scientists. Focus groups may emerge to explore a particular issue (related to science or education), and new collaborations may be formed, drawing on the strengths of workers in disparate fields. These communication networks can enhance learning about both the Earth system and effective instructional practice. DLESE can further support the adoption of effective teaching methods by linking content and pedagogy, facilitating evaluation of impacts on student learning, providing forums on effective use, and delivering relevant reports of research on learning. Finally, technology and community feedback can be combined to continuously monitor the ways in which the DLESE is used and to assess its overall impact on Earth system education. In these ways, DLESE will be responsive to community needs, help provide a supportive environment that will enhance teaching and learning about the Earth system nationwide, and assist in charting new possibilities for the Earth system education.

The educational focus of DLESE will serve all instructors and learners who are looking for quality educational resources or seeking other information about the Earth system. Simply stated, anyone who has interests in the Earth system and Earth system education is a welcome member of the DLESE community. This includes the full range of instructors and learners from formal K-16 educational settings, those who sustain and frequent institutions of informal learning such as museums, aquariums, and parks, and others in the community at large who need to know about some aspect of the Earth (e.g. journalists, public planners, interested citizens).

> Ultimately, we envision a digital library that will serve everyone including students at all grade levels, K-12 teachers, and faculty in higher education. Since Earth system education is a diverse field, we expect that the digital library will emerge from that broad-based community as groups organize and develop digital learning materials, digital learning spaces, collaboratories, and digital libraries that address their specific needs our ultimate goal is to expand the services of the library to include K-12 educators, Earth system researchers, and the public at large. *Panel 7, Portal to the Future Workshop*

Developers of Web-based educational materials often find themselves isolated within their home departments and institutions. The reasons for this are quite simple. Most faculty do not have the time nor the expertise to develop, implement, or assess high-quality Web-based learning materials. Added to this, few academic institutions have the resources to provide developers with the necessary expertise to facilitate the development of these materials.

As a developer of Web-based learning materials in the solid Earth sciences, I see DLESE's role as one of not only providing a distribution point for such materials, but also as one of facilitating, supporting, and encouraging community development of these materials. As a resource developer, DLESE can actively assist in my efforts of developing potential resources for the DLESE by providing access to technical and educational specialists, by establishing and promoting development standards and protocols, by providing assistance in field testing, and lastly, by establishing standards from which formal academic recognition for such activities can be established.

—Tom Boyd, Colorado School of Mines

the most likely source of information

A college-level biogeographer has been assigned an undergraduate teaching responsibility to develop a course on evolutionary biogeography of North America. This instructor knows the relevant material for his/her own region of the country, but not for all the other regions. S/he must retrieve similar relevant, and scientifically validated, materials over the Internet for regions outside his/her immediate experience. The instructor would like to join an Internet discussion group of professionals in Ecology, Geography, Botany, Geology, Climatology, Oceanography, Genetics, and numerous other kindred disciplines to share basic course outlines and course contents. As a minimum, the instructor believes s/he will need:

- access to current and evolutionary data for the plant and animal life in each region;
- the Tertiary-to-Recent paleo-history in each region;
- the paleogeography of North America in relation to other continents, air and ocean currents, and patterns of continental climate; and
- ways to illustrate these events on a variety of scales from continental to regional (including satellite images, 2- and 3-D visualizations, and suitable graphics).

Having developed the above resources for their own region, the task now is to search and retrieve similar materials over a broader geography. S/he has learned that DLESE is the most likely source of information. From that source, they can link to all the necessary disciplines having relevance to the topic.

—Stan Morain, Earth Data Analysis Center, University of New Mexico

Focus on Earth System Education

"DLESE should provide resources about all aspects of Earth system science education. It should include education resources about each of the Earth science disciplines, but should emphasize the Earth system and the interactions between the various spheres (atmosphere, cryosphere, hydrosphere, lithosphere, and exosphere), relations between the biosphere and other parts of the Earth system, and the relationship between humans and the Earth. Given the increasing emphasis on Earth system science, it is particularly important to provide resources for instructors who may have little experience with a systems approach and/or little knowledge and preparation in areas outside their disciplinary expertise. DLESE provides an excellent opportunity for storage and use of geospatial data. It should provide seamless links to other digital libraries and other sources of Earth science data. What sets this DL apart from other Earth science digital libraries is its focus on education."

—Panel 1, Portal to the Future Workshop

The Earth system approach provides a unifying context to demonstrate interrelationships between all components of the Earth system and humanity. This new way of understanding the Earth makes Earth system education particularly exciting at this time, while requiring major revisions to instructional materials and teaching practice (AGU, 1997). A central part of DLESE's mission is to provide the instructional resources—images, data sets, information, tools to access and use this information effectively, best practices in instructional methods, communication networks—that specifically address the needs of Earth system education. New organizing principles will be developed through DLESE that emphasize spatial and temporal relations in the Earth system, reservoirs and pathways of mass and energy, feedback mechanisms, global processes and cross-cutting principles, interactions with biota, and particularly with humanity. It is essential that users be able to navigate back and forth from the general to the specific, and horizontally and vertically through information and materials on the Earth system and from cognate disciplines.

DLESE will impact Earth system education in another important capacity: research on learning. A major challenge in all of SME&T education concerns our understanding of how students actually learn science (NSF 96-139). In the Earth sciences, there are few controlled studies documenting students' misconceptions and preconceptions about the Earth. Credible research is needed to document the ways in which students understand complex relations such as geologic time, 3-D architecture of Earth structures, and dynamic interactions within the Earth system. By providing a vehicle for dissemination, DLESE will encourage this research and its use.

Equally valuable, is an understanding of how to most effectively use DLESE and its resources. As digital technology becomes more widespread, it is even more important to document the ways in which technology-assisted learning can effectively enhance, supplement, complement or replace traditional instructional techniques. In too many instances the technology itself is a major barrier to learning. Students may spend a great deal of effort trying to learn the technology (e.g. software or instrumentation), and they may never get to the point where they actually learn anything about the content. The same may be said for instructors who may get bogged down trying to access and operate instructional technology (perhaps on incompatible machines or operating systems). DLESE must use research on effective use to continuously improve its design. It is essential that we learn both how and when to best use the materials made available through DLESE.

> One of the elements that I believe is important for DLESE to consider right at the point of origin is the effectiveness of DLESE on student learning. As education s unique contribution lies in understanding the mental operations that underlie learning and the processes of knowledge acquisition, we have a unique opportunity here to contribute to finding better ways to link the science of learning and cognition with the development of technologies for teaching and learning. Who are the students that show - and why do they show - enhanced development of cognitive facilities when presented with this mode of learning? For the long-term success of The National Digital Library s contribution to geoscience education, it is important that we consider how data acquisition, analysis and display technology have beneficial effects on students problem solving skills and on their ability to transfer these skills to new situations. That is, of course, the ultimate purpose of the entire distributive knowledge effort. *Robert Ridky, University of Maryland*

DLESE Collections

The scope of the DLESE collection was envisioned by Portal to the Future participants in a draft collection policy.

> DLESE shall collect materials that facilitate learning about the Earth system. The collection shall favor learning resources that bring the Earth into the classroom, and connect the general with the specific, theory with evidence, and the global with the local. The scope of the collection is Earth system education, with particular emphasis on interdisciplinary areas. Materials are selected to support education by giving both educators and students access to tools and resources for instruction and research. Initial priority in the building of the collection shall be given to materials for undergraduate education.
>
> Types of materials to be included in the collection:
> - data,
> - tools to look at/analyze/manipulate data,
> - methods and agents,
> - text (scientific papers, summaries, indices and abstracts),
> - images,
> - models and simulations,
> - animations and videos,
> - lesson plans and curricula, including assessment tools,
> - learning activities (guided inquiry sets, modules, problem sets, classroom and laboratory activities),
> - educational multimedia,
> - tutorials about the Earth for students,
> - interactive mini-tutorials about pedagogy, for faculty, grounded in learning science research, targeting specific pedagogical problems (e.g., students' difficulty with 3-dimensional structures, or maps, or geological time)
> - virtual field trips,
> - student portfolios (examples of student work).
>
> DLESE will accept materials in a wide range of digital formats and use technology to overcome format differences. DLESE may offer guidance to providers regarding formats and templates.
>
> —*Panel 3, Portal to the Future Workshop*

Initially, the holdings will be a mixture of volunteered materials contributed by individuals on a non-exclusive basis and links to resources produced or owned by publishers, government agencies, and other organizations. A primary goal is to collect and make available the large body of quality educational materials developed with federal funding. A second target is the extensive set of material developed independently by educators in the course of preparing classes. Most educators have a few really good exercises that they've honed over many years, but this material is generally not well disseminated. Similarly, federal agencies, professional societies, and publishers have produced large amounts of high-quality educational materials, but these, too, are often difficult to find and use. In aggregate, these materials constitute a tremendous educational resource that will be tapped to contribute to the DLESE collections. DLESE will serve to organize, index, and abstract these resources as part of its federated collections. In addition, there is the possibility that in the future new materials may be developed or commissioned by the library itself to augment collections in areas where the need has been identified by the community.

An essential component of the DLESE collections will be student-friendly access to data sets about the Earth. These have been collected by many agencies and research institutions, but are generally underutilized in educational activities. We envision access to a wide variety of archived and real-time data sets. Tools and interfaces to enable exploration of the data, and educational materials developed to enhance student interaction with the data, will also be an integral part of the DLESE holdings.

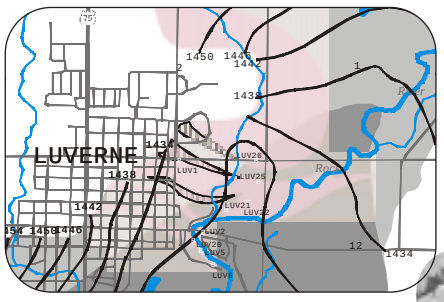
One of the highest priorities articulated by Earth science educators at all levels is the need for a system of quality assurance attached to instructional materials. The current state of the WWW is anarchistic in the sense that too much information is delivered indiscriminately, without benefit of organizing principles or standards. One of the central functions envisaged for DLESE is the development of a comprehensive system for reviewing and evaluating the diverse materials in its collections. This review system will provide a mechanism for recognizing high-quality work analogous to the peer review process traditionally used for journal articles. Once established, the review process should provide users with a high degree of confidence that they will be able to find the high-quality instructional mate-

> Many methods might be used to review and evaluate items in the DL collection and to deliver results to potential users. The geoscience community is familiar with peer review, by which referees comment on material, often anonymously. Educators are familiar with formative and summative review of material, and with a strong tradition of empirical (field) testing in classrooms. Digital librarians are familiar with review mechanisms common on the WWW, including unsolicited reviews submitted by individuals (e.g., amazon.com) and WWW-based surveys. The DL should initiate a review of methods, representation of results (e.g., in metadata), and associated software for elicitation of reviews and their support within the library. *Panel 5, Portal to the Future Workshop*

rials that they need, and creators of new materials will benefit from incentives that will result in national recognition for their contributions.

DLESE will use the review process to encourage library users to become creators of new instructional materials. There is a wealth of high-quality educational materials that have been developed by educators for personal use in local classrooms. In the spirit of sharing "best practices" DLESE will establish mechanisms to translate new materials from the personal files of instructors into the DLESE collections for national dissemination. The DLESE review process will provide an essential service by providing critical feedback to the creators about the overall efficacy and utility of their materials. The levels of review may range from informal comment in public forums (e.g., chat rooms) where creators seek advice, to establishment of focus groups that can oversee development of instructional materials on a given topic, to the formal peer review process. The review process will also provide quality assurance by verifying that minimum standards, as articulated in the DLESE review criteria, are built into the new materials. It is hoped that national recognition of new creative contributions will provide the incentive for educators to move their best materials into the public domain through DLESE.

An important consequence of the review process concerns faculty rewards and recognition. At the undergraduate level, there is broad recognition that the academic culture must change to honor and reward contributions to education. A key issue in improving science education lies in the recognition that time and creative energy spent by faculty on improving student learning both within the department and beyond is valued by colleagues and administrators (e.g. NSF, 96-139; AGU, 1997). DLESE can help foster a climate of change by providing a high-quality peer review mechanism, by documenting the impact of faculty efforts, and by providing a community center that promotes educational work.



DLESE Services

DLESE is envisioned as an active organization that reaches out to both build and serve its community. Critical to this vision are a full array of services for both users and contributors to the library.

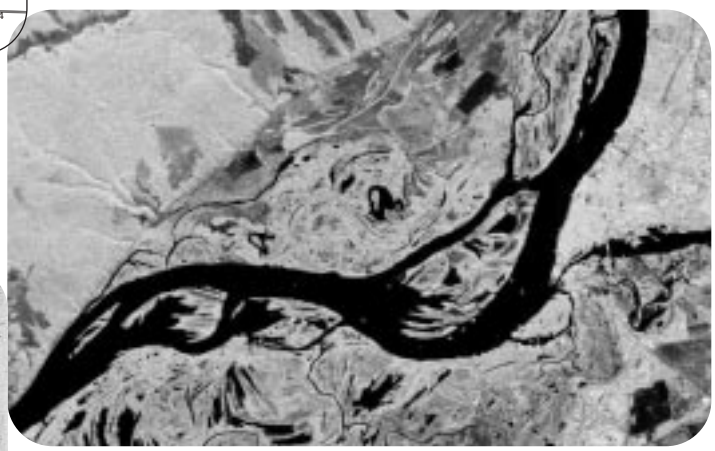
To be successful, DLESE must provide a wide range of services that support and actively promote the inherently multi-disciplinary aspects of Earth system education. The library will support the following digital and human-mediated services:

- collaboration and brokerage among Earth system science educators in their many roles as learners, researchers, and information creators;
- access to integrative tools such as models and visualizations;
- access to appropriate data and information necessary for producing Earth system educational materials; and
- applications that serve the needs of consumers with special requirements (e.g., the Americans with Disabilities Act).

The DL must provide service to two classes of clients, product consumers and product creators. By our definition product consumers are all those participants who come to the library to acquire information. Product creators are those participants who interact with the library by providing content, including digital objects.

These digital objects will fall into one of two classes: scientific data and educational content. Although we anticipate participants being both consumers and creators of digital objects, it is useful to differentiate between the two in describing the necessary services. We envision two classes of service: digital and human mediated. Digital services are those provided electronically by the DL (i.e., with minimal human interaction at time of delivery). Human-mediated services require staff assistance.

—Panel 5, Portal to the Future Workshop



promoting change, bringing recognition

A conversation in the corridor between a Dean and a Department Chair: Dean: "You know that guy Steve Jones you're sending up for tenure this year? He doesn't have much of a publication list, especially if you discount all those "gray" literature DLESE things."

Department Chair: "Don't be too quick to discount those DLESE things. I didn't think much of them either, at first. But last summer I got a message from DLESE when Steve had an item accepted by them; the message pointed to a web site where they explained their selection criteria and review procedure. It's really rigorous; they have a scientist review for scientific accuracy, plus five or more reviews for pedagogical effectiveness by educators who have used the thing in their classroom, plus a couple of other review steps that I can't remember exactly."

Dean: "Yeah, but these education things, they don't really bring recognition to the department or the university the way a good solid paper in a peer-reviewed journal does. I really think you should be discouraging your junior staff from spending time on education, above and beyond what is needed for their own students here on campus, of course."

Department Head: "Well, it looks to me that Steve's education products are bringing plenty of recognition to the university and to the department. Steve put something that he calls electronic-citation-index data in his tenure dossier and it shows that his most recent DLESE contribution, the one on Coriolis force, is being used in 450 colleges and universities, including a few dozen Research I universities. Somebody out there is noticing his stuff. And let me see if I can find that review. (Digs in pocket, finds letter) "Here it is." (Reading from the letter) "It says here: 'I have been teaching Coriolis force for 22 years. In most years, maybe 3 or 4 of the students out of my class of 20-25 students have really grasped the concept reasonably well, as opposed to being able to parrot it back. Since I started using Jones' Coriolis activity last year, I've seen a vast improvement of the teachability of this difficult concept. In the last two years the comprehension statistics have been reversed: only 2 or 3 of the students failed to grasp the concept, all the rest have a good to excellent understanding.'"

Dean: "Well, OK, you send up the documentation about the DLESE review criteria and we'll give him a fair shake. Have a good weekend."

—Kim Kastens, Lamont-Doherty Earth Observatory

Building the Library

There are three fundamental aspects to building the library:

- strategies that provide the basis for developing a resource that is grounded in the community, reflects the specific needs of Earth system education, and quickly adapts to changing community needs, novel applications, and emerging technologies;
- a governance structure that enables broad-based community ownership and input; and
- the construction of essential technical components of the library.

The initial design of DLESE is built on a large body of work which includes new directions in our understanding of the Earth system, application of best instructional practices at all levels, and new opportunities afforded by emerging technologies. The DLESE effort holds as a core value the adaption and adoption of existing good ideas, resources, and technologies. Plans and progress to date in building the library are described in the following sections.

> The first phase should reflect a simple philosophy, minimizing central costs and relying heavily on volunteer efforts and contributed resources. In this phase, a small but representative Steering Committee, informed by several function-oriented advisory groups, should provide strong, policy-level guidance and direction to an initial set of federally funded activities. *Panel 2, Portal to the Future Workshop*

Essential Design Strategies

DLESE WILL BE A DISTRIBUTED NETWORK BUILT AS A COMMUNITY EFFORT

DLESE will be built by groups from the Earth sciences, education, library, digital library and information technology communities working in a cooperative and coordinated manner. Collections, services and tools will be developed and maintained among numerous partners forming a distributed network, rather than being housed in a single centralized facility. This approach will allow the full range of talents in the DLESE community to be utilized. Existing expertise and resources can be mobilized into a broad-based effort to rapidly build the DLESE infrastructure.

To effectively coordinate the distributed DLESE effort and integrate it into a useful and complete whole, a community based governance structure and a central coordinating office have been established. The governance structure consists of a Steering Committee which is broadly representative of the diverse interests of Earth system education, and which is supported by a number of standing committees. The Steering Committee is charged with establishing policy to enable planning, construction, and management of DLESE. The DLESE governance structure is described below in "DLESE Governance". The DLESE Program Center (DPC), located at the University Corporation for Atmospheric Research (UCAR), is engaged in both the community and technical aspects of library construction and management, and is constructing the core technical infrastructure needed for the integrated effort. This work is described below in "Constructing Essential DLESE Components."

One of the first federated initiatives undertaken by DLESE was the submission of numerous proposals during spring 2000 to fund the action items defined at the Portals to the Future Workshop. This effort, coordinated by the DLESE Steering Committee, involved a number of collaborative proposals drawing on the expertise of individuals at institutions across the country. Areas targeted for immediate work include development of the community governance structure, technical infrastructure, collections, services, intellectual property policy, models for a sustainable business plan, and research on barriers to effective use of the library. A number of additional proposals were focused on building collections and services in anticipation of being incorporated into DLESE. These initial submissions demonstrated the viability of distributed partnerships in planning DLESE construction.

DETERMINING AND RESPONDING TO COMMUNITY NEEDS IS AN INTEGRAL ASPECT OF DLESE FROM THE OUTSET.

"DLESE should be dynamic and will evolve over time based on use and user input. It will provide materials and services for both users and creators as well as a mechanism for ongoing communication about materials in the DL and about other aspects of Earth system science education."

—Panel 1, Portal to the Future Workshop

DLESE must be a facility that responds to the changing interests and needs of the Earth system education community. To achieve this, several strategies are recognized as essential:

- Growth of the DLESE community must proceed simultaneously with development of the technical infrastructure.
- The Earth system education community must be fully engaged in the design, construction and governance of DLESE.
- Outreach activities must endeavor to create a broad DLESE community engaging the full range of potential users.

- Mechanisms for formative evaluation through user and creator feedback must be an integral part of the design of the library.

> It was clear during the deliberations of this panel, and those of the entire group of Workshop participants, that a strong community will be necessary for the digital library to succeed. The community will by necessity start small, but will grow as the services of the library expand to meet an ever-broadening range of user needs. Since the community membership is dynamic, the library must develop mechanisms to ensure that it is flexible enough to meet user needs as they change. By integrating users into the design process of the library, we can ensure that the library responds to its initial audience and expands to serve K-12 educators, geoscience researchers, and the public at large. *Panel 7, Portal to the Future Workshop*

Assessment of the library effort and feedback from the community are recognized as particularly important in developing a facility responding to community needs. A variety of tools are needed to allow for effortless yet comprehensive assessment of all aspects of the library from interface design to overall user satisfaction. Assessment of DLESE's impact on learning must be integrated into the library design from the outset, both to guide its development and to determine the value of the facility to the education community and to society at large.

Based on recommendations from the Portal to the Future Workshop, several initial steps have been taken to implement these strategies. The formation of the DLESE community began at the Portal to the Future Workshop and has continued throughout the past year with a broad-based effort to engage educators and technical experts in the DLESE effort. The governance structure and DLESE web-site established a variety of mechanisms for community participation in design, construction and policy making for the library. Coordination of outreach and community building activities has been established as an important activity for the DPC in parallel with the development of the technical infrastructure.

An important tool for engaging the community in building DLESE will be an annual community meeting. The first of these meetings, scheduled for June, 2000, will include a mixture of sessions providing information about DLESE to community leaders, engaging participants in design and testing of the library, and supporting the development of contributions to the library collections. Participation in the annual meeting is open to all interested parties.

Development of an evaluation plan for the library in cooperation with a professional evaluator is proposed for the upcoming year, as is development of tools to enable user surveys, tracking of use, and other mechanisms for assessment and evaluation.

AN INTEGRAL PART OF THE LARGER SCIENCE EDUCATION AND SCIENTIFIC ENTERPRISES

Earth system educators have developed a strong consensus that DLESE will be most effective if it is an integral part of the larger network of digital libraries. The National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL) is recognized as an especially important part of this network because it shares the DLESE focus on science education. The Earth sciences offer a knowledge base, skills, and philosophical approaches to problem-solving that complement those of sister science disciplines. The Earth science community also has much to gain by establishing closer ties to basic and applied science,

> Given that Earth system science focuses on the interfaces between disciplines, DLESE must actively seek out opportunities for outreach and inclusion. Thus, DLESE will foster interactions among groups by defining areas of potential mutual benefit, and by approaching target groups to explore the opportunities for interactions with the library and each other.
>
> An important step in fostering interactions is to obtain support not just from groups directly involved in Earth system science education, but also those who have influence on the policies, procedures, attitudes, and cultures of the digital library users/contributors. Such groups would include, but would not be limited to: academic administrators (school principals, deans, department chairs, promotion committees), NSF and NASA program officers, and the media (journalists). *Panel 8, Portal to the Future Workshop*

mathematics and engineering disciplines. The NSDL is envisioned as a federated library system serving all of SME&T education, just as DLESE is envisioned as a federated library system supporting learning about the Earth. By making its own federated library a fully integrated part of the NSDL, DLESE will expand both the reach of its facilities and the materials available to Earth educators. Equally important, building on its experience to date, DLESE can make fundamental contributions to the social and technical foundations needed for NSDL to succeed.

A second major priority is to establish strong connections between DLESE and the scientific research communities that study the Earth system. These linkages are essential if DLESE is to deliver the highest quality resources for learning about the Earth and provide student-friendly access to Earth data. The fundamental roles that the NSF, NASA, University Corporation for Atmospheric Research (UCAR) and the Incorporated Research Institutions for Seismology (IRIS) have played in establishing DLESE reflect the importance of these linkages and form the base for strong participation by both research scientists and educators in building DLESE. Efforts to seek out further partnerships and to utilize new methods for integrating the collecting, sharing, and use of information about the Earth are underway.

> We know that research has measured real learning benefits from information technology...The great hope is that computerized tools will bring individualized learning to all stimulating natural curiosity, providing access to the knowledge that s available in the world, and helping everyone to learn in his or her own singular style. Information empowerment takes skill information literacy... This skill one that grows more complex, yet necessary, by the minute should become everyone s right to possess, just like the ability to read is now. *Rita Colwell, 1999 Director, National Science Foundation, Beyond Barcodes:Wisdom in the Age of Information*

ACCESS FOR ALL

"For the SMETE Library to achieve its potential, it is critical that the library be accessible by all members of the SMETE community...The library could have its greatest impact by improving the knowledge base and instructional resources of those undergraduate educational institutions that historically have lacked good library and computing facilities. The SMETE Library provides the opportunity to level the playing field for students and faculty whatever their institutional affiliations, but effort is needed to achieve this goal.

The Workshop strongly recommends that accessibility should be an explicit part of the SMETE Library mandate...the library must be designed to accommodate a wide range of users and be realistic about the technology that they use. In particular, to serve the off-campus needs of faculty and students, the library should provide most core services and materials based on modem-level communication. However, not all SMETE Library services need be limited to the lowest common denominator of the current capabilities of students and faculty. Technology is growing rapidly, and the library must grow with it."

—Report of the NSF SMETE Library Workshop (NSF 99-112)

The DLESE vision is to be responsive to the needs of all users of the library. A careful balance must be struck to ensure that the "digital divide" is not broadened between those who do or do not have access to state of the art technology. Access for all is the ultimate goal of DLESE, and there is a real concern that "disparity in facilities and connectivity" will heighten current inequalities in educational opportunities (NSF 98-82). Consequently, DLESE functions must recognize the limitations imposed on many users by lack of access to, or training in, the use of new (advanced) technology. Policies must be established that will allow DLESE to maintain a position of technical leadership and excellence in Earth system education and, at the same time, ensure that its facilities and functions provide access for all.

DLESE can further address the significant issues related to inclusion and representation of all underrepresented groups in SME&T education. Students and faculty can use DLESE to develop curricula or personalized learning plans that are relevant to their own situations. In particular, the breadth of the DLESE collection will support non-traditional courses that may more directly address the interests and needs of students from groups underrepresented in SME&T. By linking research on learning styles with pedagogical information and content resources, DLESE will support a range of teaching methods appropriate for learners' diverse needs. Examples of successful programs for recruitment and retention of students from underrepresented groups can be disseminated through DLESE, as can information regarding the full range of successful career paths followed by professionals trained in the Earth sciences. DLESE can provide a suite of tools to enhance our ability to engage the broad spectrum of learners in the Earth sciences.

INTELLECTUAL PROPERTY, LIABILITY, PRIVACY

"We recognize that educational materials are intellectual property and that appropriate arrangements to protect the rights of intellectual property owners must be an integral part of the library's infrastructure and discovery system."

—Panel 6, Portal to the Future Workshop

The question of rights to intellectual property distributed in digital format over the WWW is of critical importance to all digital library initiatives (NRC, 1998). The legal precedents regarding intellectual property on the WWW are evolving rapidly, and it is essential that due diligence is applied in developing the policies that govern the operation of DLESE in this regard. Policies concerning intellectual properties are charting new ground, because unlike paper or other physical materials, it is now possible to copy, widely distribute, and modify materials that exist in digital formats (Gladney, 1999). Public access to scientific and technical databases must be balanced with appropriate safeguards of the rights of database holders to ensure protection against possible commercial misappropriation of their products (NRC, 1999).

> The challenge is in striking and maintaining the balance, offering enough control to motivate authors, inventors, and publishers, but not so much control as to threaten important public policy goals (e.g. preservation of the cultural heritage of the nation, broad access to information, promotion of education and scholarship). *NRC, 2000, A Question of Balance: Private Rights and the Public Interest in Scientific and Technical Databases*

There are also related legal issues concerning liability and privacy in the use of DLESE. It is conceivable that materials delivered through DLESE may pose certain risks to users that may impact the DLESE staff or creators of DLESE materials (NRC, 1998). Steps should be taken to protect DLESE from exposure to litigation in such cases. The question of personal privacy was anticipated at the Portals to the Future Workshop:

> ...it will be necessary to develop an authentication system that will allow only authorized users access to the resources of the library. (Users could be authorized through many different channels such as being students or faculty in a university, a state-wide school system, government office, etc.) Once a user accesses the library, it will be possible for the staff who maintain the access system to track usage by school or institution, but not by individual user, thus maintaining the privacy of users. The systems for security, authentication, and data gathering will have to be developed by the technical staff of the library under the direction of the Steering Committee. Rules concerning acceptable use of the library and user data will need to be addressed in the contracts with institutions that license the content, and should be developed by the experts hired to prepare model contracts.
>
> *—Panel 6, Portal to the Future Workshop*

It will be necessary to commission external expertise in developing policies regarding intellectual property, liability, and personal privacy. The DLESE Steering Committee is engaged in this work as part of its development of Articles of Federation and strategic plans (described below). A collaboration with Columbia University Press is providing initial models to guide policy development.

INDICATORS OF SUCCESS

DLESE's goal is to enhance learning about the Earth. Evaluation of the project will be measured against these indicators of success put forward at the Portal to the Future Workshop.

Governors of DLESE should be watchful for signs of success or failure. Among the indicators of success is that the library:

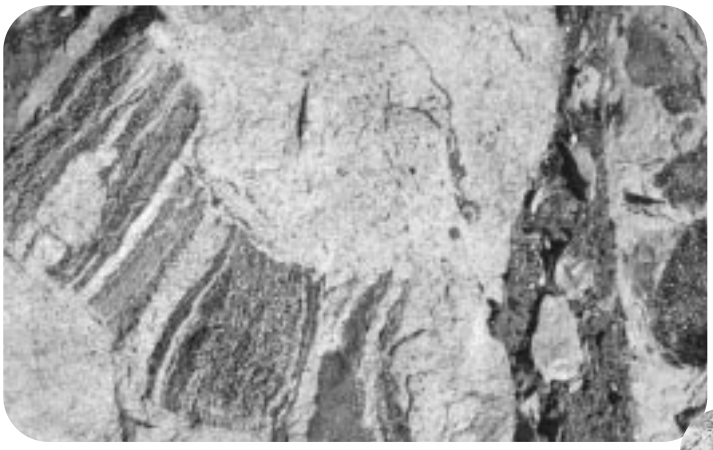
- is widely used;
- is linked to educators on large scales (e.g via textbooks);
- has an integrative effect in respect to data sources, tools, etc.;
- is self organizing and adaptive;
- is attractive to commercial organizations;
- is the best among many (implying focus, emphasis on "good" data, etc.);
- effectively utilizes "seals of approval" (e.g. , from USGS & NSTA);
- matches resources to constituents;
- resembles the Consumers Union model;
- exhibits excellence in design and architecture;
- provides a distillation function (not just filtering);
- leverages existing and new assets;
- provides a framework/infrastructure for new initiatives; and
- resembles the Nature Conservancy model: measuring things yields changing attitudes.

Perhaps the foremost indicator of success is the emergence of new attitudes and practices, on large scales, linked to use of the library.

—Panel 2, Portal to the Future Workshop

DLESE Governance-Coordinated Cooperation with Maximum Community Guidance

Critical to the construction and management of DLESE is a governance structure in which all partners and constituencies feel well represented and can contribute as equal players. This governance structure must simultaneously ensure that the library is built as an integrated system while providing for broad-based input to address diverse community needs. To enable coordination and policy decisions for this group, the Portal to the Future Workshop participants recognized the need for a central governance body as described in the following extract.



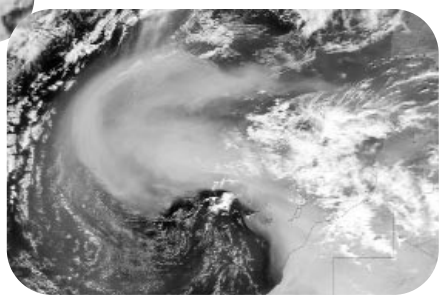
Governing Principles. The purpose for imposing a governance structure on the library is to align library efforts with the advancement of Earth system education. This includes ensuring that the associated decision makers are accountable to a large community of users with a complex variety of interests in the Earth system and in the Earth sciences broadly defined, including educators at all levels (primary, secondary, undergraduate, graduate, and community outreach), providers of data (NASA, NOAA, IRIS, UCAR, etc.), and information technology specialists. Hence the governance structure and the selection of governors must:

a) reflect the interdisciplinary nature of the Earth system;
b) exploit the alliances that already exist within the scientific and educational communities being served;
c) represent the needs of a highly diverse population of learners; and
d) instill a sense of "ownership" among library constituents.

Governing policies for the library shall enfranchise all of the contributing partners, attract new partners to the federation, and create a sense of communal responsibility for contributing to and promoting the effectiveness of the library. This includes fostering a sense of responsibility among content providers for library excellence, in part by offering the providers expert assistance, tools that enable content creation, and forms of recognition for their work. In addition, library governance must achieve balance along two dimensions: advancement versus responsiveness, and centralization versus decentralization. To this end, the governance process should:

a) encourage decisions (by sponsors and contributors as well as by library managers) that position the library to meet well-recognized needs, and simultaneously to lead the community toward improved educational practices and creative uses of advanced digital technology;
b) foster reliance, to the greatest practical extent, on federated and contributed resources, limiting the central functions to those required for interoperability and overall effectiveness.

Together, all of the above considerations imply the need for a small but broadly representative Steering Committee, informed by several function-oriented advisory groups and chartered to provide strong, policy-level guidance and direction for library efforts. Though the Steering Committee may alter its structure as the library evolves, the initial framework should include four advisory groups focused on users, services, collections, and technical matters. The work of the advisory groups should be complemented with broad-based, electronically facilitated input directly from the community of library user/creators. The Steering Committee also should establish a framework for including federated members in the library effort and establishing: a) a fair and open use policy;



b) guidelines on intellectual property, with non-exclusive rights to materials being held by the creators;
c) minimum technical standards for effective networking across and between federated library components; and
d) responsibilities that lead to a robust, sustainable system for collecting, maintaining, and disseminating materials or services that are incorporated in the library.

[DLESE governance] will enable broad participation, foster a culture of users as providers of library contents, and emphasize the Earth-system characteristics that make DLESE a uniquely valuable educational resource. The initial governance structure is viewed as an interim step in creating a suitable structure for library management in the long term. The long-term governance structure will be matched to a long-range business model developed with comprehensive economic and market analyses, and reflect mutually beneficial relationships with the Digital Earth Initiative, the SMETE library, and other related projects.

—Panel 2, Portal to the Future Workshop

A Steering Committee was nominated by the organizing committee for the Portal to the Future Workshop and elected by the workshop participants in October, 1999. Based on the recommendations of the Portal to the Future Workshop, the Steering Committee developed a governance plan that reflects DLESE's

focus on Earth system education at all levels, its commitment to users and creators of educational materials, and its federated character. This plan was ratified by the Portal to the Future participants in February, 2000. The governance document, names of Portal to the Future workshop participants, organizing committee, and conveners, and the current Steering Committee members and standing committee chairs are given in the appendices.

> Finding ways to distribute (such) information to all who want it equitably, reliably, and in keeping with the principle of full and open exchange as a sine qua non of progress in science is the greatest challenge (this committee) identified while conducting its study. *Bits of Power (NRC, 1997)*

The Steering Committee is currently engaged in developing Articles of Federation. This document will articulate a common value system held by all members of the DLESE partnership, including the importance of all of the Earth science disciplines in teaching and learning about the Earth system and a philosophy of sharing resources equitably. In addition, mechanisms will be established to ensure that the distributed library network functions as a single integrated facility. Guidelines that enable searching and sharing of information among the federated library partners and with other digital libraries are essential. The goal is to enable maximum flexibility and allow contribution by a wide variety of partners with interests spanning Earth system education without sacrificing the seamless nature of the library interface. The Articles of Federation will be completed by December, 2000.

> To be successful, the library must have built-in and sustainable mechanisms to motivate users to belong, use their services, and contribute to its collections. Users of the library must be able to link to other digital libraries and services (as they exist and emerge) in a seamless, transparent manner. *Panel 7, Portal to the Future Workshop*

Over the next three years, the Steering Committee will focus on continued development of the social and technical structures required to move DLESE from planning and design to full implementation. A second major charge to the Steering Committee is to develop a structure for long-term stability of the library. Included must be a business plan that is financially sustainable, a long-term governance model, and a policy addressing the intellectual property rights of users and contributors. (Recommendations of Portal to the Future Panels 2 and 6).

ESTABLISHMENT OF THE COMMITTEE STRUCTURE

As outlined in the governance document, four standing subcommittees guide the work of the Steering Committee. The goals of these committees are to:

- provide a mechanism for broad community input into all aspects of library development;
- undertake projects and activities appropriate to the focus of their committee; and
- advise and assist the Steering Committee in the DLESE effort.

The DLESE Steering Committee has named an interim chair for each committee to establish committee membership and begin its work. To facilitate communication with the Steering Committee, a Steering Committee member has been named to each committee as a liaison. Full committees will be elected in fall 2000 and each will select their chair at that time. Based on the recommendations of the Portal to the Future Workshop, the interim chairs have developed the action plans described below.

User Committee:

William Prothero, University of Santa Barbara, Interim Chair
Jim Hays, Lamont-Doherty Earth Observatory, Steering Committee Liaison

The role of the User Committee is to ensure that DLESE responds to the needs of the full breadth of the user community.

The composition of the committee should be broadly representative of the DLESE membership as the user community evolves.

Action Plan:

- Develop a community outreach plan that draws in the full breadth of the Earth system education community and reaches out to sister disciplines and other library efforts.
- Establish mechanisms for community feedback and library evaluation that ensure that the library responds to community needs.
- Develop a set of incentives for all kinds of users and producers/developers in order to maintain and sustain high levels of participation.
- Develop a prestigious award to recognize and reward outstanding contributions in the development and production of materials for the digital library.
- Establish a yearly community workshop for inspiration, information, and planning.

Collections Committee:

Kim Kastens, Lamont-Doherty Earth Observatory, Interim Chair
Kate Wittenberg, Columbia University Press, Steering Committee Liaison

The role of the Collections Committee is to oversee development and maintenance of the library collection and peer review mechanism. The Collections Committee is charged in the short term to establish the collection policy and peer review system. In the longer term, they will make recommendations for enhancing the collection to better serve Earth system education.

Action Plan:

- Circulate the draft collection policy and criteria for acceptance to potential users for comments.
- For each category of materials, establish what 'well documented' means and define the minimal criteria for completeness.
- Determine what methods will be used to document and judge pedagogical effectiveness and develop specifications of minimum standards, recognizing that different methods and standards may be appropriate for different kinds of submissions.
- Research recommendation engines and methods for review and evaluation.
- Establish mechanisms for providing academic career credit to creators/suppliers of materials.
- Develop specifications for prototype collections of materials anticipated for DL.

Services Committee:

Mohan Ramamurthy, University of Illinois, Urbana-Champaign, Interim Chair
Barbara DeFelice, Dartmouth University, Steering Committee Liaison

The Services Committee is charged with guiding implementation and ongoing evaluation of library services. As in all parts of the library, it is essential that services respond to the needs of the community, thus the committee is encouraged to work with the User Committee in identifying priority services.

Action Plan:

- Survey users regarding service needs.
- Assist in the development of user feedback mechanisms to allow testing of services.
- Engage in design discussions for tools and interfaces to data.
- Work with the DPC in guiding implementation of human-mediated and electronic services.

Technology Committee:

Tom Boyd, Colorado School of Mines, Interim Chair

The role of the Technology Committee is to ensure that DLESE effectively employs existing and developing technology. This committee will both provide guidance in making technical decisions and make sure that DLESE establishes and maintains a leadership role in adopting and creating information technologies. In addition, it is charged with assisting DLESE in forming seamless interfaces to other digital resources.

Action Plan:

- Advise DPC software engineers on selection of technologies needed to implement core DLESE functions.
- Mediate DPC developer access to technical resources resident in the community at large.
- Coordinate and develop standards for interoperability among users, the DPC, and other resource providers.
- Host a workshop designed to share expertise between the committee and key DLESE developers.
- Develop a technical education program for the DLESE community.
- Assist the DPC in developing policies to promote, in cooperation with other digital libraries in the NSDL, interoperability among the federated DLESE partners.

Constructing Essential DLESE Components

Translating the vision and strategies for DLESE into a viable working library is the central challenge of constructing the library. The planning and design of the essential DLESE components must in every case start with a consideration of what the community needs, and how individuals will use the system. The governance structure and outreach effort described above have established the linkages necessary to foster these vital communications between the DLESE community and the distributed network of DLESE builders. Working closely with the community, the DPC has begun designing and prototyping the essential components of DLESE: the discovery system, the collection, and user services.

THE DISCOVERY SYSTEM

The discovery system lies at the heart of DLESE, providing the means to help educators and learners find materials, tools, and information that they need, when they need it. Holdings can be searched to allow users to link Earth concepts with examples from a particular time or place, with supporting data, and with relevant information on student learning and teaching methods. Portals to Earth data, supported by relevant curriculum materials, will engage learners in the processes of discovery and inquiry about the Earth system. Of primary importance is a system, whose internal operations are transparent to the user, which provides rapid discovery of requested resources.

Community input has formed the basis for the discovery system design. The implementation of the system will utilize existing technology where applicable as a framework upon which to build more DLESE specific architecture. The library interface will be developed to 1) allow maximum flexibility and specificity in finding desired resources and presenting them to the user, and 2) to allow a user to effectively access, integrate, manipulate, analyze, render, and visualize data and information from a variety of sources. Ultimately, the library will provide the user with seamless connections to resources housed in other digital libraries. The library interface will give access to tools that will aid in the creation of new educational materials that combine, build upon, or are inspired by the existing and growing collections.

The essential components of the discovery system can be divided into four groups:

- a graphical user interface that allows users to interact with the system;
- an underlying system architecture that connects the user interface to a search engine, resource database, and other supporting services;
- cataloging practices that describes resources in the data base and enable searching; and
- protocols that allow the discovery system to access information about resources at distributed sites.

> Collectively, these technologies have the ability to provide access to world-wide resources; facilitate the accumulation and presentation of data; and enable communication, interaction and collaboration among students and instructors to improve the practice of teaching and the experience of learning...Ultimately, the technology tools should become transparent as they engage the user with the material, enabling immersion in the learning process on an individual basis or as part of a community...Inquiry should be non-linear, guided by the interests of the user, and offer flexibility in the path of inquiry and the depth of investigation *Information Technology Workshop (NSF 98-82)*

The discovery system is currently under construction at the DPC in collaboration with the Alexandria Digital Library at the University of California, Santa Barbara. The DPC is actively developing partnerships with other groups that have developed expertise in digital libraries, interoperability, searching and other related fields, including the San Diego Supercomputing Center and the digital library effort at Stanford University. To ensure that the discovery system meets the needs of the Earth system educators, a design methodology consistent with best practices in designing highly interactive systems is being used (Lewis and Rieman, 1994; Gould et al., 1991; Nielsen, 1994). The central tenets of this methodology are: early and continual involvement of users in the design process, a focus on real users and their tasks, and iterative design guided by frequent formative evaluations (Gould et al., 1991). DLESE has solicited descriptions of anticipated use of the library in the form of short, narrative statements from the diverse interests of the Earth system education community. These user scenarios are being translated into system requirements by the DLESE technical staff. Continued, iterative discussion with community members further describe desired functionalities, which then form the basis for prototyping and testing activities.

For example, initial mock-ups for parts of the user interface enabling searching and returning information have been constructed. Design priorities distilled from the recommendations of the Portal to the Future Workshop were used to develop the mock-ups that were then tested on educators in the Colorado Front Range area and refined. Additional testing will take place at the first annual DLESE Community Meeting.

Interoperability

Developing a distributed library requires that the discovery system be highly interoperable. Interoperability refers to the ability to communicate a search request across a number of sites and receive results from all. For example, if the discovery system is to access information held at another site, interoperability is needed to allow the discovery system to present a query in such a way that the other site can translate that request and return the results the user needs. Similarly, interoperability is required if a tool or service developed by a DLESE contributor is to be accessed through the discovery system.

Interoperability is both a technical and social issue. On the technical side, protocols must be developed and implemented that allow both the transfer and interpretation of information between sites. Developing a highly interoperable discovery system is a design priority that will be implemented on all scales in the system design. Partnerships that allow the use of state of the art techniques to maximize interoperability are essential. On the social side, DLESE contributors and partners must be willing to work together to maximize the amount of interoperability that is possible by agreeing to technical standards for communication and operation. The DLESE governance structure, particularly through the Technology Committee, provides a forum in which these conversations can take place, agreements can be reached, and guidelines can be put in place. All these efforts will position DLESE well to interact with other digital facilities including NSDL.

Cataloging

"Resource cataloging is a core activity in the construction and ongoing maintenance of any library, be it physical or digital. Resources are the items that make up the contents of the library. For DLESE, these are educational materials, simulations, images, data interfaces and tools, interactive laboratories, information about teaching methods, list-servers etc. Cataloging is the process of classifying a particular resource using the library's metadata schema. Metadata schemas provide a structured way to describe the resources in a library using predefined fields that should only be assigned certain values. For example, these schemas typically contain fields such as 'Title' (referring to the title of a resource), 'Description' (a free text description of a resource), 'Subject' (typically keywords chosen from a controlled vocabulary list), and so on."

—Tammy Sumner, University of Colorado

The key to an effective discovery system is to catalog resources using metadata that anticipates the expected range of uses of these materials. The Earth system education community has asked for totally new organizational structures that reflect the new emphasis on the Earth system approach (AGU, 1997), and which also support new pedagogical philosophy and practice in diverse instructional settings. To enable searching specific to Earth system education, DLESE metadata will combine rigid cataloging on a number of axes using controlled vocabularies and fields where free text can be entered. Cataloging will include standard fields like topic and type of resource. However, the strength of the discovery system will rest on new dimensions of cataloging as diverse as:

- levels of instruction;
- geospatial referencing (e.g., Zhu et al., 1999; Hill et al., 1999);
- temporal referencing of absolute and relative geologic time;
- overarching concepts (e.g., convection in thunderclouds, magma chambers, the mantle, and mid-ocean hydrothermal systems);
- Earth system processes (e.g., plate tectonics, thermal-hyaline oceanic circulation; orographic weather patterns);
- thematic approaches that cut across traditional disciplinary boundaries (e.g., environmental justice, natural hazards, resource utilization);
- pedagogical approaches and suitability for learning style;
- implementing the National Science Education Standards; and

> What is Metadata? Put simply, metadata is data about the data; that is the attributes associated with the data. Each entry in the DL has associated metadata. You can make a list of the attributes for each type of entry. These will include the temporal attributes of the entry (when was the entry drawn, written, made, taken or completed), the spatial attributes of the entry (the geographical area encompassed by the entry), the software and hardware needed to use the entry, as well as the type of entry and the confidence the user may place (the validity) in the entry. *Panel 4, Portal to the Future Workshop*

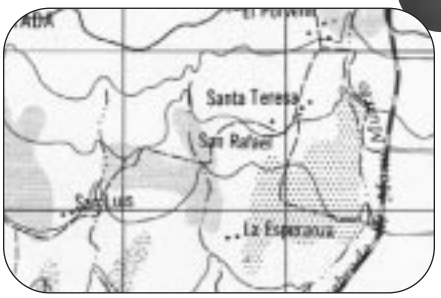
- level of review or associated assessment data.

The cataloging must be flexible enough to accommodate totally new advances in learning about the Earth that have yet to be envisioned.

The development of these classifications will require extensive community input in developing the metadata schema and associated controlled vocabularies. The resulting cataloging system will allow informed searches in quest of the specific attributes the user is most interested in finding, a major improvement over generic search engines currently available on the web.

The metadata for DLESE will be entered using an industry standard that will allow different library systems to interpret the information. The IMS standard (IMS 2000), with extensions for geospatial referencing, is currently being used in the DLESE testbed because it is specifically designed to describe educational resources and is suitable for accommodating the wide range of resources envisioned for DLESE.

Cataloging DLESE resources is a time intensive activity requiring expertise in Earth System education. To enable the library holdings to grow quickly, much of the cataloging will need to be done by contributors to the library. DLESE will work with the community to develop a culture in which new contributions to the library include needed metadata. Guides to best cataloging practices, services that automate entry of some information, and tools to enable contributors to simply and correctly enter needed information will be developed. DLESE can also serve as a testbed for new tools which use artificial intellegence techniques to extract classification information.



The DLESE discovery system, when fully implemented, has the potential to change the ways in which instructors teach and students learn. Detailed cataloging can allow users to connect content resources with information on pedagogy, to find local examples of general concepts, and to select resources suitable in different learning environments or that are most appropriate for students with particular learning needs. Through DLESE, inquiry- and discovery-based learning can be facilitated by allowing teachers and learners to navigate through the network of holdings, across disciplinary boundaries, and at any level of understanding. The underlying technology that supports DLESE should be transparent to its users to optimize the focus on learning.

COLLECTIONS

The DLESE collection is envisioned as the resource of first choice for educators and learners interested in the Earth system. There are three major aspects to managing the collection: gathering resources, reviewing resources, and assessing the completeness of the collection.

Gathering Resources

The Collections Committee and the DPC staff are actively building the DLESE collections so that they will be sufficiently large and well catalogued to be exciting and useful to the Earth system education community when the discovery system becomes operational. These collections are imagined as growing from individual contributions of resources, the aggregation of new and existing collections, and the organization of broadly distributed web resources that already exist in the public domain. DLESE is currently engaged in identifying existing resources, recruiting new partners, and encouraging the development of new resources that are compatible with the discovery system. Self-defined groups are already forming to develop resources to be disseminated through DLESE that meet the needs of particular parts of the community. In the future, DLESE should be recognized as the primary vehicle for national dissemination of new Earth system educational materials.

The collection will consist initially of contributed resources. An initial, small, design testbed collection, for the purposes of developing the metadata schema and discovery system, is currently under construction at the DPC. A larger operational testbed collection will be developed to test the discovery system and the infrastructure supporting assessing and cataloguing resources. This larger collection will anticipate the many uses of DLESE by the broadest range of interests in Earth system education. Development of an operational testbed collection requires much more than simply finding good materials that are already available through existing sources. Linkages must be established throughout the community to recruit users and contributors and to solicit feedback on needs and priorities in the collections.

Reviewing Resources

The DLESE collections will include both reviewed and unreviewed materials to balance the need for efficient access to a wide variety of materials with the desire for quality assurance. Materials held in the "core" collection will be reviewed according to codified criteria that have been approved by, and widely distributed to, the community. Building on the work of other digital libraries (e.g., Eibeck, 1996), the Collections Committee is developing selection criteria based on community input. Initial review criteria that have been suggested include:

- accuracy, as evaluated by scientists;
- importance/significance;
- pedagogical effectiveness (e.g., is there evidence that student learning has occurred?);
- well-documented (e.g., data shall have metadata, lessons shall have rubrics, etc.);
- ease of use for students and faculty;
- inspirational or motivational for students; and
- robustness/sustainability.

—Panel 3, Portal to the Future Workshop

Two mechanisms are currently proposed for evaluating materials in DLESE. The first is envisioned as a traditional peer-review procedure. The second mechanism is a web-based community review process that combines automated tracking of frequency of use of a resource, an on-line questionnaire for users of the resource, and solicited review of scientific content.

DLESE will provide links to other established sources of information, where materials may have been reviewed at varying levels by other institutions external to DLESE (e.g., professional societies, publishers, federal agencies). The level of review these materials received at their host institutions will be displayed through the DLESE metadata systems, to provide a context for users to determine the level of confidence they will place on the materials.

In addition, DLESE will also maintain an unreviewed public domain that will serve as a testbed for materials under development. A full range of formative assessment tools for improving materials are envisioned in this area including peer commentary, testing, and evaluation services. Informal communications between creators and users of new materials are an important mechanism to help move new materials into the formally reviewed parts of the DLESE collections.

Users are seeking materials on a huge range of topics. The DL provides added value by being inclusive while providing powerful search and classification capability. The library will identify these resources as relevant but unreviewed, applying the philosophy of caveat emptor.

The DL itself can serve as a testbed for reviewing and field-testing educational materials, and positive feedback via communication networks hosted by the DL could provide the basis for the documentation of educational effectiveness required for an item to move into the peer-reviewed section of the DL.

The dynamic nature of DLESE allows the review process to continue past the initial submission and acceptance. Correspondents can report on ways in which the materials were adopted or adapted to meet special circumstances, comment on the effectiveness of the activity, or suggest ways to more effectively use the activities. This continued commentary may be attached to the original submission; thus the original contribution will continue to gain value as experience demonstrates how to best use the materials. *Panel 3, Portal to the Future Workshop*

Assessing the Collection

An important part of managing a physical library collection is determining where the collection needs additions and how it should be pruned. The DLESE collection will also need to be assessed to make sure it has a scope and balance in line with user needs.

"If this were an ordinary book-library being built from scratch for a new community, there would be a librarian watching the growth of the collection to make sure it was complete and well-balanced. With a library based on contributed resources, there is a danger that the library will grow in a lopsided way. It could become rich in materials based on data from a well-organized and well-funded government agency, while remaining poor in resources pertaining to a more diffuse and less organized discipline, or could grow rich in materials for undergraduates while remaining poor in materials for K-3."

—Report from the Collections Committee

To begin to address this issue, the Collections Committee has proposed a process for comparing the existing resource set to the request by users for resources. In this way, unsuccessful searches will influence the growth of the collection in new directions. Similarly, unused resources can be identified and removed from the collection.

SERVICES

A wide variety of services have been identified by the Earth system education community which are desirable and important components to the library. The goals for services will be 1) to promote collaboration and sharing among Earth system educators in their many roles as instructors, learners, and researchers; 2) to instruct and assist users and creators in finding data, information, and tools that they need; and 3) assist consumers with special requirements (e.g., the Americans with Disabilities Act).

The desired services can be divided into several groups:

- services that support use and management of the library (e.g., automatic delivery, help services, user-feedback mechanisms);
- services that support the contribution of resources to the library and review of materials (e.g., cataloging tools, attaching user comments to resources, tools of collection developers); and
- services that support better learning about the Earth (e.g., chat rooms, clearinghouse services).

The following services were recommended by Portal to the Future Workshop particitpants.

The Digital Services DLESE should provide to users include:

Querying Services - DLESE must develop and maintain software that allows consumer access to the contents of the library. This service must be sufficiently flexible so that a broad range of consumers, with a variety of needs, have easy and intuitive access to DLESE resources. Objects stored in DLESE should be searchable through a variety of tags, such as: subject area, geographical area, time (i.e., object creation date, data creation date, etc.), learning style, educational standards, data type, etc.

Software Services - DLESE must ensure the development and maintenance of software that allows users to visualize, integrate, model, and simulate basic Earth science data sets (e.g., earthquake epicenters, mean temperature, ocean current patterns, etc.). In addition, DLESE should develop and provide links to appropriate models and simulations operated and maintained by other creators.

Automatic Delivery Services - These include services that automatically or routinely distribute digital content to a list of subscribed users. Such services are currently available from commercial enterprises like PointCast and CarlUncover for delivery of real-time news and tables of content for journals, respectively. In this way, every time a new item is catalogued in the library, or if external resources are indexed or abstracted by the library, interested users will be notified automatically.

Clearinghouse Services - In addition, DLESE should provide clearinghouse services. Examples include: 1) access to peer-reviewed information, 2) distribution of news and temporally important data sets, 3) announcements for a variety of opportunities (e.g., employment, research, educational, etc.) for students and professionals, 4) coordination of student, synoptic data collection and course support, 5) coordination, distribution, and facilitation of student collected data, 6) publication of K-16 research, 6) access to Earth science experts, 7) matching of students with mentor students, 8) promotion of DL products, 9) provision of a forum for teachers' collaborative ESS projects, and 10) dissemination of Earth system science career exploration.

Technology-Aided Collaborations - These include content-based electronic discussion forums, groupware services, virtual seminars, interactive virtual field trips, and desktop video conferencing.

User Feedback Services - DLESE will develop mechanisms for consumer feedback on products and services in a field testing phase, and after product implementation. Information gathered should include user profiles and product usage statistics. This information will be stored as metadata associated with the product and be distributed to consumers, creators, educational researchers, and DLESE managers.

Human-mediated services will include:

Help Desk Services - DLESE will provide user assistance in finding resources, in DLESE software usage and in fulfilling specialized requests such as layering specialized data requests (e.g., layering agribusiness information on top of normalized vegetation index).

Professional Development Services - DLESE should be proactive in support of educators involved in Earth system education. This could include the organization and presentation of virtual and real experiences (e.g., workshops, conferences, training, mentoring). DLESE will provide teaching and learning examples: e.g., cooperative learning, alternative assessment, creating web sites, searching the web, use of rubrics, use of technology, use of electronic discussion groups, alternative teaching methods (inquiry-based, problem-based learning, direct teaching, etc), developing multiple intelligences, and electronic portfolios.

Brokered Collaborative Activities - DLESE will lead in fostering relationships within the Earth system community. These collaborations could be in the form of mentoring, consumer/supplier, and co-PI relationships. In addition, the brokered services should match specific learning needs with appropriate products, partnerships, and/or mentors. The library can also define theme sessions (in response to community requests), working groups to explore certain topics, and may even commission "white papers" on specific issues.

Maintenance and Sustainability - Guaranteeing the integrity and stability of DLESE materials will provide one of its key distinctions from the current World Wide Web. Integrity includes accessibility, currency, correctness; stability includes operability, periodic upgrades, and monitoring of product usage. This is a fundamental and non-negotiable function of the library. Materials in the variety of raw and value-added databases, descriptive text, software, model code, lesson plans, pedagogical innovations, user reviews, and so forth are all subject to this necessary service. Expecting that materials will be distributed across the Internet, special strategies and considerations for maintenance and stability of DLESE holdings must be developed. A skeletal context for product maintenance and stability should be designed and invoked at the outset, and then evolved through actual development of the library.

Quality Control and Assurance - DLESE must establish a policy and procedure to insure high-quality, up-to-date, and reliable digital objects.

The library must support digital object creators. Support will include:

Gathering Services - While the DL must encourage volunteered contributions, it must actively identify community needs and then solicit contributions from the community to fill these needs. If solicitations fail, DLESE should look into developing the materials internally or contracting with a creator. In addition, DLESE must take the lead in negotiating consumer access to digital objects created by institutional creators (e.g., USGS, USDA, EPA, NASA).

Creator Services - DLESE must identify open, technical standards (e.g., ISO9000) for data distribution, interface interaction, etc. Contributors to the library will be encouraged to conform to these standards. Furthermore, the DL will broker lines of communication between product creators, consumers, and education specialists. Finally, DLESE will assist product developers by supplying sample data sets, development standards, access to specialized expertise, relationships with educational specialists, and field-testing. Additional services related to e-commerce, security, authentication, and licensing will be developed as needed.

—Panel 5, Portal to the Future Workshop

A variety of services enabling community discussion and communication have been implemented to support the DLESE governance structure and community involvement in the DLESE project. An initial set of services that support use and management of the library, contribution of resources to the library, and review of materials have been proposed for development by a number of collaborators. Discussions of the role of DLESE in undergraduate, K-12, and informal education have also been initiated which will identify services that could have a major impact in supporting learning about the Earth. The Services Committee is engaged in identifying the services desired by the Earth system education community using a web-based survey and community discussions. As DLESE evolves, this committee will provide a mechanism for assessing the array of services.

Long Term Planning for Sustainability

As a community resource, DLESE will only be successful if it is sustainable into the future. Thus the development of business plans, intellectual property policies, and other strategic planning were considered high priorities by Portal to the Future Workshop participants. The DLESE Steering Committee has immediately engaged in a strategic planning process designed to identify goals and objectives needed as the basis for a business plan.

The development and early stages of implementation of DLESE are expected to rely heavily on direct or indirect federal funding, primarily from NSF, NASA, and the in-kind cooperation of other federal agencies. If the digital library is envisioned as contributing to the public good, there is a responsibility for federal funding to maintain at least the core functions of the digital libraries. A coordinated plan to fund the digital library initiative among the contributing federal agencies is needed.

DLESE may be viewed as a facility that broadly contributes to the educational and research mission of the geosciences community. The NSF/GEO Facilities Plan (NSF, 1999) identifies several common themes as part of an integrated view of the future: the access revolution, integration across disciplines, interagency coordination, data quality, and continuing exploration. DLESE will play a major role in advancing these themes for established GEO facilities such as UCAR, IRIS, Ocean Drilling Program (ODP), and planned programs such as EARTHSCOPE and Digital Earth. There is an essential link between GEO facilities and education—the health of our community requires vital contributions from both research and education (NSF 97-171). Long-term funding for DLESE may possibly derive in part through support from existing GEO-sponsored facilities or, conceivably, as a new member of the network of GEO-sponsored facilities.

"The GEO-sponsored facilities, while having primarily a research-driven mission, also have ambitious education and outreach programs in place and in development. These programs typically reflect the missions of the facilities, yet are designed for broad impact at multiple educational levels: graduate and postdoctoral undergraduate, pre-college, and public outreach."

—GEO Facilities Plan 1999-2003 (NSF 99-139)

As it looks to the future, the DLESE community must consider other sources of funding from the Earth system community, and from the private sector. Sources of revenue may include: fees for service, community taxation, creation of saleable intellectual property, and grants. DLESE does have the potential to generate revenues. Discussions at the "Portals to the Future" Workshop considered the possibilities of charging individual user fees, selling licenses for institutional use, selling products developed

by the library (e.g., databases), advertising, and seeking benefactors from the community (e.g. PBS/NPR model) to generate revenues to supplement funds derived from grants from federal agencies or private foundations.

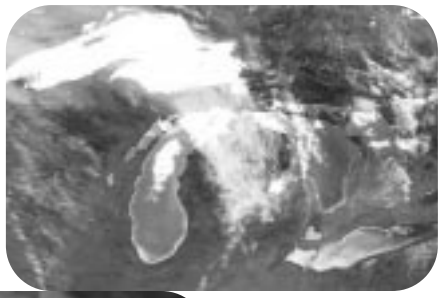
There is a clear message from the community that DLESE must maintain an open fair use policy for access to library holdings (NSF 99-112; NRC, 1999). However, there are numerous library functions that may result in the creation of original materials such as indexing, abstracting, or other information services that hold value, and thus, provide opportunities for revenue generation. The recommendations of the Portal to the Future Workshop called for a "mixed ownership" model:

> In this model, the Digital Library for Earth System Education...(acquires) content from educators, as well as directing users to other content providers. The digital library negotiates non-exclusive rights to original content, involving contracts with contributors. This contract should include a clause stating that copyrighted material has been cleared by the contributor. There exists the potential for revenue from licensing of the original content, and thus an increased potential for self-sufficiency.
>
> *—Panel 6, Portal to the Future Workshop*

There is great promise in forming strategic liaisons with the private sector (e.g., publishers, suppliers of educational supplies). DLESE may be able to obtain right of access to copyrighted materials, thus increasing the "critical mass" of holdings in the library, while providing publishers with greater exposure through the communication networks that DLESE can offer. Models for these types of partnerships are being developed by Columbia Earthscape and will inform the DLESE strategic planning effort.

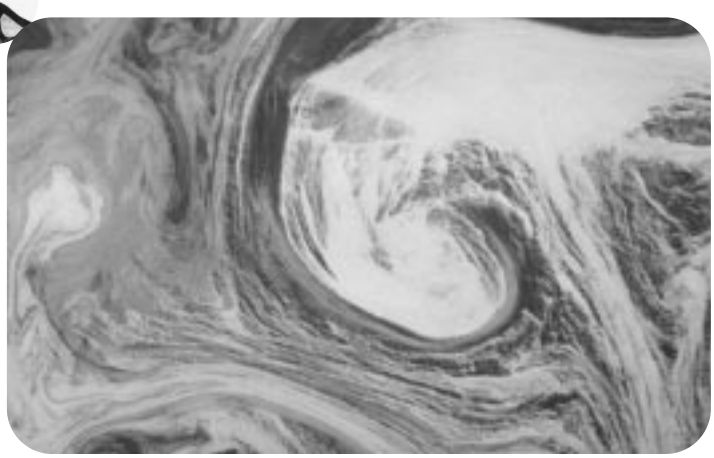
The question of long-term sustainability for all of the digital library initiatives remains a huge question. To effectively design and implement the long-term business plan for DLESE expertise is needed at this formative stage to a) conduct market research to identify potential users and address their needs and interests; b) identify revenue generating mechanisms that will be accepted by the community; c) develop a sound business plan; d) seek out natural alliances among other digital library initiatives to maximize efficiency in development; e) leverage existing funding with support from additional funding sources; and f) determine the appropriate level of central administration, support staff, and infrastructure required to ensure the success of DLESE.

"...there was little consensus about how best to address questions of economic viability and sustainability, as well as equity of access for all people who wish to utilize this resource as a teaching and learning tool...there is a great need to identify potential users and patterns of use of such a resource. ..Revenue is likely to be a continuing problem and must be confronted directly and early in the development process if this DL is to remain viable and able to grow and adapt to changing user needs and advancing technology.
—Developing a Digital Library for Undergraduate Science, Mathematics, Engineering, and Technology Education (NRC, 1998)



Looking to the Future

In the past year, DLESE has moved from the dreams of a few people to a large community effort. A community vision for the library has been articulated, broadly discussed, refined, and endorsed. Mechanisms to support a broad-based collaborative effort that responds to community needs have been established and are being tested. Prototypes are under construction. DLESE sparks the excitement of educators, librarians, and digital library experts in a wide variety of venues. Many have stepped forward to participate in the governance structure, in the list-servers informing design and policy, in constructing collections and services, and in the development or contribution of materials for the collection. Yet the most exciting work lies ahead: transforming our dreams into a working facility, filling it with the best our science has to offer, and using DLESE to truly transform learning about the Earth. The goal of this report is to enable this greater task. Having set forth the need, the vision, the plan, and the progress to date, the door is open for participation by all. By engaging in this work together, we build the foundations of a healthy planet for tomorrow.



I dream of students solving problems that they really care about,thinking hard about Earth processes in order to come up with an answer to a problem that they think is truly important. I envision students learning basic facts because they are important to figuring something out, not learning facts because they have to. Molly Fritz Miller, Vanderbilt University

References

American Association for the Advancement of Science, Project 2061 Science for All Americans, Washington, DC, 1989.
http://www.project2061.org//tools/sfaaol/sfaatoc.htm

American Geophysical Union, Stout, D. L., Bierly, E. W., and Snow, J. T., (eds.), Scrutiny of Undergraduate Geoscience Education: Is the Viability of the Geosciences in Jeopardy?, Washington, DC, 1994.

American Geophysical Union, Ireton, M.F.W., Manduca, C.A., and Mogk, D.W., (eds.), Shaping the Future of Undergraduate Earth Science Education-Innovation and Change Using an Earth System Approach, Washington, DC, 1997.
http://www.agu.org/sci_soc/spheres/

American Geophysical Union, Shaping the Future of Undergraduate Earth Science Education: Where are we three years later?, EOS Transactions, v. 80, n. 46, p. f115-120, 1999.

Bush, Vannevar, As we may think, The Atlantic Monthly, v. 176, p. 101-108, 1945.

Colwell, Rita, Beyond Barcodes: Wisdom in the Age of Information, Address to the National Press Club, 1999.
http://www.nsf.gov/od/lpa/forum/colwell/rc990429npc.htm

Colwell, Rita, Complexity and Connectivity: A New Cartography for Science and Engineering, Keynote Address to the American Geophysical Union Fall Meeting, 1999.
http://www.nsf.gov/od/lpa/forum/colwell/rc991213agu.htm

Eibeck, P., (ed.), Criteria for peer-review of engineering courseware on the NEEDS database, IEEE Transactions on Education, Special Issue on the Application of Information Technologies to Engineering and Science Education, Sept. 1996.

Gladney, H. M., Digital dilemma: Intellectual property, synopsis and views on the study by the National Academies' Committee on Intellectual Property Rights and the Emerging Information Infrastructure, D-Lib Magazine, v. 5, n. 12, 1999.
http://www.dlib.org/dlib/december99/12gladney.html

Gould, J.D., Boies, S., and Lewis, C., Making usable, useful, productivity-enhancing computer applications, Communications of the ACM, v. 34, p. 74-89, 1991.

Gregorian, Vartan, President's Essay—From the 1998 Annual Report, Carnegie Foundation, 1998.
http://www.carnegie.org/sub/about/pessay98.html

Hill, L.L., Frew, J., Zheng, Q., Geographic Names - The implementation of a gazetteer in a georeferenced digital library. D-Lib Magazine, v. 5, n. 1, 1999.
http://www.dlib.org/dlib/january99/hill/01hill.html

IMS Global Learning Consortium, Inc., IMS Learning Resource Meta-data Information Model (Version 1.0), 2000.
http://www.imsproject.org/metadata/mdinfo01.html

Lewis, C., and Rieman, J., Task-centered User Interface Design, an electronic text, 1994.
http://home.att.net/~jrieman/jrtcdbk.html

Mogk, D. W., and Zia, L., Addressing opportunities and challenges in evaluation and dissemination through creation of a national library for undergraduate science education. Geosciences Information Society Proceedings, v. 27, p. 17-22, 1997.

National Research Council, National Science Education Standards, National Academy Press, Washington, DC, 1996.
http://stills.nap.edu/html/nses/

National Research Council, Bits of Power: Issues in Global Access to Scientific Data, National Academy Press, Washington, DC, 1997.
http://bob.nap.edu/html/BitsOfPower/

National Research Council, Developing a Digital Library for Undergraduate Science, Mathematics, Engineering, and Technology Education-Report of a Workshop, National Academy Press, Washington, DC, 1998.
http://www.nap.edu/books/0309059771/html/index.html

National Research Council, A Question of Balance: Private Rights and the Public Interest in Scientific and Technical Databases, National Academy Press, Washington, DC, 1999.
http://www.nap.edu/html/question_balance

National Research Council, The Digital Dilemma: Intellectual Property in the Information Age, National Academy Press, Washington, DC, 2000. http://books.nap.edu/html/digital_dilemma

National Science Foundation, Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology, (NSF 96-139), Arlington, VA, 1996.
http://www.nsf.gov/cgi-bin/getpub?nsf96139

National Science Foundation, GEO Facilities Plan, 1999-2003 (NSF 99-139), Arlington, VA, 1999.
http://www.nsf.gov/cgi-bin/getpub?nsf99139

National Science Foundation, Geoscience Education: A Recommended Strategy (NSF 97-171), Arlington, VA, 1997.
http://www.nsf.gov/cgi-bin/getpub?nsf97171

National Science Foundation, Information Technology Its Impact on Undergraduate Education in Science, Mathematics, Engineering, and Technology (NSF 98-82), Arlington, VA, 1998.
http://www.nsf.gov/cgi-bin/getpub?nsf9882

National Science Foundation, Report of the NSF Science, Mathematics, Engineering, and Technology Education Library Workshop (NSF 99-112), Arlington, VA, 1999.
http://www.dlib.org/smete/public/report.html

Nielsen, J., Usability Engineering, Academic Press, Inc., Boston, MA, 1993.

Report of the Santa Fe Planning Workshop on Distributed Knowledge Work Environments, Digital Libraries, 1997. http://www.si.umich.edu/SantaFe/

Tewksbury, B.J., Project Kaleidoscope Featured Essay, 1999.
http://www.pkal.org/10thann/pages/essays/7799_essay.html

Wattenberg, F., A National Digital Library for Science, Mathematics, Engineering, and Technology Education, D-Lib Magazine, v. 4, n. 10, 1998. http://www.dlib.org/dlib/october98/wattenberg/10wattenberg.html

United States Congress, House Committee on Science, Unlocking Our Future-Toward a New National Science Policy, 1999.
http://www.house.gov/science/science_policy_report.htm

United States Geological Survey, USGS in a Changing World, Circular 1172, 1999.

Zhu, B., Ramsey, M., Ng, T., Chen, H., and Schatz, B., Creating a large-scale digital library for georeferenced information D-Lib Magazine, v. 5, no. 7/8.
http://www.dlib.org/dlib/july99/zhu/07/zhu.html

Photo Credits

Title Page: R. Heather Macdonald, College of William and Mary; Sandy Shipley and Tom Lowell, University of Cincinnati. **Page** 4: Cathryn A. Manduca, Carleton College. **Page 5:** W. Patrick Hinely, Washington and Lee University. **Page 6:** NASA Goddard Space Flight Center Visualization Analysis Lab; W. Patrick Hinely. **Page 7:** R. Heather Macdonald. **Page 9:** Open Skies Aerial Photography, US Geological Survey Circular 1181; Armistead Booker, College of William and Mary. **Page 12:** W. Patrick Hinely. **Page** 14**:** R. Heather Macdonald; Frank W. Ireton, American Geophysical Union. **Page 17:** Laboratory for Atmospheres, NASA's Goddard SpaceFlight Center. **Page 19:** Lindgren, R.J., and Landon, M.K, U.S. Geological Survey Water Resources Investigations Report 99-4157; SIR-C/X-SAR image from NASA/Jet Propulsion Laboratory; R. Heather MacDonald. **Page 23:** Mary Savina, Carleton College. **Page 25:** Cathryn A. Manduca; SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE. **Page 28:** W. Patrick Hinely. **Page 29:** Rick Hazlett, Pomona College. **Page 30:** DMA topographic map, US Geological Survey Circular 1181; NASA Landsat 7. **Page 33:** Tim Vick, Carleton College. **Page** 34**:** W. Patrick Hinely; SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE. **Page 35:** Tim Vick ; NASA STS 45 Image. **Page** 44**:** Katie Manduca, Lincoln at Mann Elementary School

Appendix I

Portal to the Future Workshop, Geoscience Digital Library, and Other Activities Informing this Report

PORTAL TO THE FUTURE WORKSHOP: PLANNING, ORGANIZATION, AND ACTIVITIES

The Portal to the Future workshop, held August 8-11, 1999 at Coolfont Resort in Berkeley Springs, West Virginia brought together 59 leaders from undergraduate, K-12, and informal Earth system education, digital libraries, and information science to develop an action plan for building DLESE.

The workshop agenda was developed by an organizing committee representing the various communities essential to DLESE. They developed a workshop structure and process that would allow participants to efficiently develop a common vision of the library, address the major aspects of its development, and draft a report, within the three-day workshop. Panels were organized around eight questions:

- What are the appropriate scope and focus for an Earth system education library?
- How should the library be governed, managed, and funded?
- What are the key features of a valuable Earth system education library collection?
- How will users find what they need in the library?
- How will the library facilitate Earth system education beyond providing access to materials?
- How will we ensure fairness with regard to intellectual property?
- How will the library respond to the needs of its user communities?
- How will the library foster interactions between and among groups involved in Earth system education?

The organizing committee recognized the need to solicit the broadest representation among Earth scientists, educators, information technology specialists, and others who are already involved with other digital library efforts. Panelists were invited to participate based on consideration of professional expertise, established record of achievement, specific knowledge or skills related to Earth system education or information technologies, geographic distribution, and type of institution.

Prior to the workshop, participants were encouraged to explore digital library resources on the WWW, to become familiar with background reports on Earth system education and digital libraries, and to begin their panel discussions electronically. During the workshop, time was divided between plenary sessions to develop a common vision and work in panels to develop detailed action plans. The workshop began with a presentation by organizing committee member Mike Goodchild (Alexandria Digital Library at University of California, Santa Barbara) that explored the value of a digital library for Earth system education and introduced a preliminary vision developed by the organizing committee. The remainder of the workshop expanded on, revised, and detailed this vision. Participants voted unanimously to move forward with the project by establishing a steering committee and organizational structure. The recommendations of the panels were available for review by workshop participants and by the larger community. The final panel reports are available online from the DLESE homepage (www.dlese.org).

Portal to the Future Workshop Conveners:
Donald Johnson, University of Wisconsin
Cathryn Manduca, Keck Geology Consortium
John Snow, University of Oklahoma

Organizing Committee:
Tim Ahern, Incorporated Research Institutions for Seismology
Bryan Aivazian, Wyoming Center for Problem Based Education
Elizabeth Ambos, California State University-Long Beach
Tom Baione, American Museum of Natural History
Lillian "Boots" Cassel, Villanova University
Mike Goodchild, University of California, Santa Barbara
Jim Hays, Lamont-Doherty Earth Observatory of Columbia University
Mary Marlino, University Corporation for Atmospheric Research
Dave Mogk, Montana State University
Randy Sachter, Nederland Elementary School
Ray Thomas, University of Florida
Bob Wilhelmson, University of Illinois

Participants:

Panel 1: What are the appropriate scope and focus for an Earth system education library?

Heather Macdonald, College of William and Mary (Panel Chair)
Howard Burrows, Raytheon/NASA
Shelley Canright, NASA Headquarters
Tim Foresman, University of Maryland, Baltimore County
Don Johnson, University of Wisconsin
Sudha Ram, University of Arizona
Mike Smith, American Geological Institute

Panel 2: How should the library be governed, managed, and funded?

Dave Fulker, University Corporation for Atmospheric Research, (Panel Chair)
Erma Anderson, National Science Teachers Association
Chris DiLeonardo, Foothill-DeAnza Community College
Blanche Meeson, NASA Goddard Space Flight Center

Stan Morain, University of New Mexico
Dave Simpson, Incorporated Research Institutions for Seismology
John T. Snow, University of Oklahoma

Panel 3: What are the key features of a valuable Earth System Education library collection?

Kim Kastens, Lamont-Doherty Earth Observatory of Columbia University (Panel Chair)
Karen Ciccone, North Carolina State University
Beth Duff, US Geological Survey
Mike Goodchild, University of California, Santa Barbara
Doug Gordin, SRI International
Martin Ruzek, University Space Research Association

Panel 4: How will users find what they need in the library?

Jay Skiles, NASA Ames Research Center (Panel Chair)
John Butler, University of Houston
Lillian "Boots" Cassel, Villanova University
Barbara DeFelice, Dartmouth College
Ben Domenico, University Corporation for Atmospheric Research
Jordan Hastings, University of California, Santa Barbara
Thomas Wason, University of North Carolina, Chapel Hill

Panel 5: How will the library facilitate Earth science education beyond providing access to materials?

Mohan Ramamurthy, University of Illinois, Urbana-Champaign (Panel Chair)
Tom Boyd, Colorado School of Mines
Jim Hays, Lamont-Doherty Earth Observatory of Columbia University
Janet Morton, US Geological Survey
Bob Myers, Wheeling Jesuit College
Randy Sachter, Nederland Elementary School
Owen Thompson, University of Maryland

Panel 6: How will fairness with regard to intellectual property be ensured?

Kate Wittenburg, Columbia University Press (Panel Chair)
Michelle Lamberson, University of British Columbia
Linda Musser, Pennsylvania State University
Perry Samson, University of Michigan
Ray Thomas, University of Florida

Panel 7: How will the library respond to the needs of its user communities?

Bob Ford, Westminster College of Salt Lake City (Panel Chair)
Bryan Aivazian, Wyoming Center for Problem Based Education
Frank Ireton, American Geophysical Union
Mary Marlino, University Corporation for Atmospheric Research
Flora McMartin, University of California, Berkeley

Panel 8: How will the library foster interactions between and among groups involved in Earth system education?

Karen Kemp, University of California, Berkeley (Panel Chair)
Elizabeth Ambos, California State University, Long Beach
Jo Dodds, O'Leary Junior High School
Ed Geary, Geological Society of America
Ira Geer, American Meteorological Society
Catherine Johnson, Incorporated Research Institutions for Seismology
Steve Semken, Dine College

Other Participants:
Alan Gaines, NSF/GEO
Steve Griffin, NSF/CISE
Nahid Khazenie, NASA Headquarters
Cathryn Manduca, Carleton College
Mike Mayhew, NSF/GEO
Dave Mogk, Montana State University
Dotty Stout, NSF/EHR
Ming-Ying Wei, NASA Headquarters

GEOSCIENCE DIGITAL LIBRARY PROTOTYPE EFFORT

A second major activity providing guidance in the development of this plan is the Geoscience Digital Library (GDL) prototype building effort. This collaboration was funded in Summer, 1999 by NSF through the Geoscience Education, Element 2: Application of Digital Libraries to Undergraduate Earth Systems Education program (NSF 99-44). To capitalize on the distributed strengths of the Earth sciences community, the GDL project is a collaboration among six organizations with diverse disciplinary foci:

- Program for the Advancement of Geoscience Education (PAGE) and Unidata, at the University Corporation for Atmospheric Research;
- Incorporated Research Institutions for Seismology;
- Earth System Science Education Consortium (ESSE);
- Keck Geology Consortium;
- Alexandria Digital Library, University of California, Santa Barbara;
- Center for Life Long Learning and Design, University of Colorado at Boulder.

The initial GDL development effort was guided by the DLESE Steering Committee and the Portal to the Future workshop reports. Its activities have included mocking up a potential user interface, initiating discussion and testing of library classification schemes, exploring mechanisms for communication

between different digital collections, development of a plan for library building, and initial steps in setting system design requirements using user scenarios developed by the DLESE community. The GDL work continues as part of the DPC activities.

OTHER OUTREACH ACTIVITIES

To inform the Earth system education, library, digital library, and information technology communities about the DLESE effort and engage them in developing the community vision of the library and action plan, a flyer and website were developed in fall 1999. The flyer was distributed at meetings of the American Association for the Advancement of Science, American Geological Institute, American Geophysical Union, American Meteorological Society, Geosciences Information Society, Geological Society of America, National Science Teachers Association, Project Kaleidoscope Change Agents Roundtable, Sigma Xi, and at informal meetings and interactions throughout the year. Presentations and discussions of library plans were held at the October 1999 meeting of the Geological Society of America in Denver, Colorado (town meeting) and associated meeting of the Geosciences Information Society, the December 1999 meeting of the American Geophysical Union in San Francisco, California (special session), the January 2000 meeting of the American Meteorological Society, and the January 2000 Digital Earth meeting in Santa Barbara, California. Over 200 people were involved in these sessions. Information was also distributed on listservers to the geoscience education, water education and ocean sciences communities, as well as on listservers for Heads and Chairs of Geoscience Departments, Earth System Science Education Consortium, Keck Geology Consortium, and Council on Undergraduate Research. As a result of these efforts, individuals

- submitted user scenarios which became the basis for the system design process and many of which are presented in this report;
- reviewed the preliminary report and provided comments on the vision and plan;
- volunteered for committees and joined list-servers; and
- became involved in proposals for DLESE resources, collections and services.

Appendix II

A Governance Plan for DLESE, a Digital Library for Earth System Education

During an August 1999 conference, titled "Portal to the Future: A Digital Library for Earth System Education" and sponsored by NSF and NASA, attendees endorsed several steps toward creating the subject library (DLESE). These steps included forming a DLESE Steering Committee, and part of the Steering Committee's charge was to draft a governance plan and to circulate it for ratification by the conference participants. This document is intended to fulfill that charge, and it is based in significant part on the Panel 2 Report, which grew out of the Portal to the Future effort and is part of the overall conference report.

I. OVERALL GOVERNING FRAMEWORK

The Digital Library for Earth System Education (DLESE) will be guided under a two-phase governance model to facilitate an initial start-up stage followed by a longer-term operational structure. The first phase reflects an emphasis on applying technology and building a community of users. The guiding philosophy during this phase will be simple: minimizing central costs and relying heavily on volunteer efforts and contributed resources. In this phase a small but broadly representative steering committee, informed by several function oriented advisory groups, will provide strong, policy level guidance and direction to an initial set of federally funded activities. These central efforts should enable broad participation, foster a culture of users as providers of DLESE contents, and emphasize Earth system characteristics that make DLESE a uniquely valuable education resource.

The second DLESE phase will differ from the first primarily in a shift of emphasis toward a sustainable business model, though technology advances and community building certainly will continue. It is believed that agreement on such a model will become more practical when 1) experience has been gained in the application of digital-library technologies, broadly defined, to the practice of Earth-system education, 2) educators in Earth system science have been engaged as users of and contributors to DLESE, and 3) the relevant economic and market analyses have been performed. A governance model for the second phase has yet to be defined, as it must incorporate the aforementioned long-range business model.

The purpose for imposing a governance structure on DLESE is to align library efforts with the advancement of Earth system education and with other digital library initiatives. The start-up phase of DLESE will rely heavily on efforts funded by government agencies, so the Phase I governance model is intended to incorporate the relevant agency objectives.

II. THE DLESE STEERING COMMITTEE (PHASE I)

Responsibility for governing the DLESE effort is vested in the DLESE Steering Committee. This is a small but broadly representative Steering Committee, informed by several function oriented advisory groups and chartered to provide strong, policy-level guidance and direction for DLESE efforts. Though the Steering Committee may alter its structure as DLESE evolves, the initial framework will include four advisory groups focused on collections, users, services, and technical matters. The work of the advisory groups will be complemented with broad-based, electronically facilitated input directly from the community of DLESE user/creators.

A. Steering Committee Membership

Prominent among the purposes of the governance model is ensuring that DLESE is beneficial to a large community of users with a complex variety of interests in the Earth system and in the Earth sciences broadly defined, including educators at all levels (primary, secondary, undergraduate, graduate, and community outreach), providers of data (NASA, NOAA, IRIS, UCAR, etc.), and information technology specialists. Hence the selection of members for the DLESE Steering Committee is intended to

- reflect the interdisciplinary nature of the Earth system;
- exploit the alliances that already exist within the scientific and educational communities being served;
- represent a highly diverse population of learners.

The Steering Committee is envisioned as tying together the broad interests of the wider DLESE community, and illustrating in its own operation the concept of federated cooperation. The 14 initial Steering Committee members—nominated by the organizing committee for the Portal to the Future workshop, and elected as a slate by the workshop participants—are listed below.

Beth Ambos, California State University, Long Beach
Bryan Aivazian, Wyoming Center for Problem Based Education
Barb DeFelice, Dartmouth College
Chris DiLeonardo, Foothill-DeAnza Community College
Dave Fulker, University Corporation for Atmospheric Research
Mike Goodchild, University of California, Santa Barbara
Jim Hays, Columbia University
Don Johnson, University of Wisconsin
Cathy Manduca-Chair, Carleton College
David Mogk-Vice Chair, Montana State University
John Snow, University of Oklahoma
Tom Wason, University of North Carolina at Chapel Hill (resigned 5/00)
Bob Wilhelmson, University of Illinois
Kate Wittenberg, Columbia University Press

The Steering Committee elects its own chair annually and will invite participation by observers and commentators from government agencies and the private sector. The members' terms of service will be three years, with one third of the Committee being replaced in each year. Details of this rotation procedure as it pertains to the initial membership will be worked out by the Steering Committee.

As vacancies arise, nominations for new members will be solicited from the wider DLESE community. From these nominations, a slate of proposed new members will be put forward by a small group, comprising the current Steering Committee chair and the chairs of the four standing committees on Collections, Users, Services, and Technology. This slate will be presented to the full DLESE community for ratification. Voting members of this community will define themselves by registering their interests (as users and/or creators) through an (on-line) mechanism that can be accessed easily from the DLESE home page.

B. Steering Committee Charter

The Steering Committee is chartered to provide strong, policy-level guidance and direction for DLESE efforts, consistent with the following governance principles and reporting responsibilities.

1. Principles of DLESE Governance

The scope of DLESE is intended to be multidisciplinary and international, serving a diverse community of learners and educators at many levels of scientific sophistication. Efforts to build DLESE will combine voluntary contributions by community members with funded activities. DLESE's "holdings" are a federated collection of digital artifacts from many sources, and only a fraction are acquired and maintained in central repositories. In other words, DLESE is envisaged to be a federation.

The DLESE Steering Committee is charged to enfranchise all of the contributing partners, attract new partners to the federation, and create a sense of communal responsibility for contributing to and promoting the effectiveness of DLESE. This includes fostering a sense of responsibility for excellence among content providers, in part by offering the providers expert assistance, tools that enable content creation, and forms of recognition for their work. In addition, the Steering Committee is charged to seek balance along two dimensions: advancement versus responsiveness and centralization versus decentralization. To this end, the Steering Committee charge includes:

- instilling a sense of "ownership" among DLESE constituents;
- encouraging decisions (by sponsors and contributors as well as by DLESE managers) that position DLESE to meet well recognized needs, and simultaneously, to lead the community toward improved educational practices and creative uses of advanced digital technology; and
- fostering reliance, to the greatest practical extent, on federated and contributed resources, limiting the central functions to those required for interoperability and overall effectiveness.

The Steering Committee also is charged to create an effective framework for including federated members in the DLESE effort and establishing:

- a fair and open use policy;
- guidelines on intellectual property, that will encourage use for educational purposes while respecting the intellectual property rights of the creators;
- technical standards that ensure interoperability and effective networking across and between federated DLESE components; and
- responsibilities that lead to a robust, sustainable system for collecting, maintaining, and disseminating materials or services that are incorporated in DLESE.

2. Reporting Responsibilities of the Steering Committee

In general, the DLESE Steering Committee is responsible to the community of DLESE users. While this community is being identified, the Steering Committee will report its decisions to and seek feedback from those who participated in the Portal to the Future conference and members of the DLESE subcommittee listservers. Reports of meetings and other documents and activities related to DLESE will be posted in a timely manner on the WWW, to inform and to encourage feedback from the community of DLESE users and potential users. As DLESE and its user community evolve, matters of reporting and feedback will be revisited by the Steering Committee, with input from the Users Subcommittee.

3. Subcommittees

As mentioned previously, the Phase 1 governing framework includes four advisory groups, i.e., subcommittees, focused on collections, users, services, and technical matters. Four interim subcommittees have been formed, with chairs and Steering Committee liaisons as listed below. Complete subcommittees will be formed after this governance plan is ratified by the DLESE community.

Collections Chair: Kim Kastens, Columbia University
SC Liaison: Kate Wittenberg
Users Chair: Bill Prothero, University of California, Santa Barbara
SC Liaison: Jim Hays
Services Chair: Mohan Ramamurthy, University of University of Illinois, Urbana-Champaign
SC Liaison: Barb DeFelice
Technology Chair: Tom Boyd, Colorado School of Mines
SC Liaison: Tom Wason (resigned 5/00)

Subcommittee slates will be chosen on the principle of broad representation across all DLESE interests and constituents, though individual seats will not be reserved for a given constituency (such as a discipline, type of institution, or level of instruction). Instead, nominees will be proven community leaders whose records reflect the broad interests of the DLESE community.

Terms of service for subcommittees will be three years, and the selection process for Subcommittee membership will be the same as for the Steering Committee (nominations from community, slate chosen by SC Chair and Subcommittee Chairs, ratification by community).

C. Steering Committee Operations

A few important aspects about how the DLESE Steering Committee will operate and make decisions are listed below.

Decision Making—A quorum will require eight of the fourteen Steering Committee members, whether meeting in person or deciding an issue via e-mail interactions. Consensus will be the standard basis for decision making, and if there is contention, a two thirds majority vote will be required. Issues to be voted upon will be articulated via a proposed motion, followed by discussion, followed by a vote tally.

Advisory Groups—To the greatest practical extent, Steering Committee actions will be informed by the deliberations of the subcommittees whose interests pertain. Additional subcommittees or working groups may be convened as needs arise.

Day-to-Day Operation—To facilitate day-to-day DLESE activities and to seize short-fuse opportunities for federal funding or establishing strategic relations, the Chair is empowered to make quick decisions that fall within generally understood policies. Need for additional officers beyond the Chair is not anticipated.

Record Keeping—DLESE has established its own domain and web site (http://www.dlese.org/), and this currently is maintained by the Program for the Advancement of Geoscience Education (PAGE) at UCAR. The Portal to the Future Conference (Coolfont) web site (http://geo_digital_library.ou.edu/) at the University of Oklahoma will exist until these sites and activities can be meshed, more fully developed, and transferred to a permanent support entity.

Working Relationship with UCAR—A short-term working arrangement between DLESE and UCAR has been established wherein the Steering Committee plays advisory, policy defining, and nurturing roles in respect to the Geoscience Digital Library (GDL). UCAR also serves as host for DLESE governing activities.

III. GOVERNANCE-RELATED ACTIONS

This section provides a partial list of actions that are directly related to the Steering Committee's role in governing DLESE. Each action is accompanied by an approximate date of completion, which depends-in some cases-on gaining funds or finding partners to perform the work.

1. (By 15-Feb-2000) Circulate this document among the Portal to the Future conference attendees for comment and ratification.
2. (By 28-Feb-2000) Develop a skeleton draft of DLESE's "Articles of Federation." This will describe the concept of federation, including pertinent principles of interoperability.
3. (By Dec-2000). Finalize the Articles of Federation, reflecting the dual nature of DLESE: 1) a resource for finding or discovering digital material that facilitates Earth-system science education and 2) a forum for community involvement. A useful metaphor is to liken the federation to a big circus tent. DLESE serves as a center pole, but the entirety of the tent is determined by the federation's success in utilizing community energy fo raising additional tent poles.

4. (By 28-Feb-2000) Develop a Memorandum of Understanding that articulates a working relationship between DLESE and UCAR, including the Steering Committee's role in guiding the GDL effort and UCAR's role in supporting the Steering Committee.
5. (By Dec-2000) Create a development plan for DLESE that contains a vision statement, an interim business plan, and strategies to address interoperability, sustainability, and intellectual property issues.
6. (By mid-2001) Perform an economic analysis, an intellectual property analysis, and a needs assessment, incorporating the factors listed below plus experience gained from the prototype efforts.

   Community Assets
   - Knowledge, judgement, raw materials (data, simulations, visualizations, diagrams, explanations, etc.) ;
   - Potential for helping the publication industry adapt to the digital/Internet age; and
   - Potential interfaces with other digital library efforts.

   Possible Bases for Revenue
   - Usage-based micropayments, subscriptions...;
   - Macropayments from libraries...;
   - "Finder Fees" from commercial providers;
   - Intellectual property licensing; and
   - Corporate/personal underwriting (per PBS/NPR model; formally connected to memberships?).

   Intellectual Property Constraints and Opportunities
7. (By end-2001) Conduct a DLESE-wide conference in which to adopt a business plan and a corresponding long term governance model. Utilize advances in the Digital Earth Initiative and knowledge gained in the economic/market study and the prototyping efforts.
8. (Long-Term): Establish the central facilities (offices, professional/technical/managerial staff, administration, infrastructure, etc.) needed to operate DLESE.
9. (Ongoing) Monitor the DLESE effort, paying special attention to the success/failure indicators articulated in the Panel 2 report from the Portal to the Future conference.

Acknowledgments

This report is a community effort. It began as the outgrowth of the Portal to the Future: A Digital Library for Earth System Education Workshop, funded by NSF grant EAR 99-06648. However, it has grown to reflect the efforts of the DLESE community over the past year. We would like to acknowledge the special roles played by NSF Program Directors Mike Mayhew, Alan Gaines (GEO/EAR) and Dorothy Stout (EHR/DUE), and NASA Program Manager Ming-Ying Wei in encouraging and funding the initial phases of DLESE.

Many have made important contributions both to the report and to DLESE. The report rests heavily on the work done at the Portal to the Future Workshop which was convened by John Snow, Don Johnson, and Cathy Manduca. The shape and breadth of the community vision reflects the excellent work done by the Portal's organizing committee and panel chairs. Their follow through after the workshop was particularly important in launching the DLESE Steering Committee and guiding the work of the standing committees. The efforts of those who convened sessions and gave presentations at professional society meetings were essential in obtaining broader feedback on the vision and engaging new people in the effort. A special thank you goes to the community members who provided ideas, user scenarios, quotations, images, reviews of the preliminary report, and general input. These contributions are an important part of both the report and the initial DLESE design. Cliff Jacobs and Jewel Prendeville provided a particularly valuable viewpoint in reviewing the preliminary report. Lastly, there would not be much to report in "Building the Library" without the hard work of Mary Marlino and the DPC staff. They have responded to an ever-expanding job with good humor and excellent results. We are very grateful to Eileen McIlvain for the excellent support she has given the Steering Committee and to Lynne Davis for her work on the web pages.

In producing the report, we were much assisted by Martin Ruzek and Heather Macdonald who worked particularly hard on the images, editing, and other details. Diane Smith assisted with the final editing. The cover design was kindly donated by Elaine Bean. The report was designed and produced by Anne Heike. The administrative support of Tanya Guthrie at University of Oklahoma was especially important in organizing the Portal to the Future workshop.