PROJECT SUMMARY

Intellectual merit: As human-induced environmental change continues, society is facing an increasing array of pressing environmental challenges. Answers to these complex challenges must be informed by coordinated, long-term, interdisciplinary research. Following a very successful two decades of science, training and outreach, the Long Term Ecological Research (LTER) Network is poised to address a set of new initiatives to be pursued in response to these environmental ìGrand Challenges.î It is this background which sets the stage for intensive Network-wide planning activities that started at the LTER All Scientist Meeting held in September 2003, and that, if funded, would continue over a 24-month period. This planning effort has the following specific objectives over the duration of the planning grant period:

Objective 1: Develop a plan for LTER network-level science, technology, and training through:

- new initiatives in long-term thematic, regional, and network-scale science,
- increasing the capabilities of scientists/sites (e.g., cyberinfrastructure, technical expertise) to perform research and education for the new environmental challenges,
- fully integrating graduate and undergraduate education into Network-level science and synthesis, and
- integrating LTER and non-LTER sites and networks into a comprehensive international network of networks for ecological research.

Objective 2: Explore alternative governance, planning and evaluation structures for managing LTER Network science. These new models might include:

- a governance structure to serve and support a more highly coordinated scientific network,
- a governance structure for network-wide science planning and evaluation,
- a process for seamless integration of new sites and collaborative networks, and
- an implementation plan to achieve these objectives.

Objective 3: Envision and plan for education, training, outreach, and knowledge exchange activities to link LTER science with application needs.

This will include:

- establishing priority areas and key targets for education and outreach activities,
- exploring mechanisms to facilitate collaborative science,
- enhancing the participation of groups underrepresented in the discipline,
- developing skills and mechanisms for better exchange of knowledge among scientists, policymakers, and resource managers.

Broader Impacts: This planning activity will create the framework necessary for the LTER Network to (1) increase the scale and scope of activity needed to address a number of ecological Grand Research Challenges, (2) achieve a higher level of coordination and complementarity among the research sites, (3) incorporate new, enabling technologies into LTER research, (4) broadly train the next generation of ecologists, and (5) improve and increase the exchange of knowledge between science, managers and policy makers. In doing so, the LTER Network will actively pursue a new level of collaboration, synthesis and integration to address challenging ecological questions now and in the future.

PROJECT DESCRIPTION

I. INTELLECTUAL MERIT

1. Motivation and Objectives

The nature and scope of ecological research has changed considerably over the past century. Initially, ecology was a relatively descriptive science focusing on short-term observations in relatively pristine systems, often conducted by one or two individuals and their students. As the discipline has matured, ecological research has gradually become more integrative, interdisciplinary and collaborative (McIntosh 1985, Golley 1993), and the spatial and temporal scales of research questions and methods have vastly expanded. Moreover, ecologists now fully recognize that pristine systems are rare or non-existent; instead, the human footprint is global and pervasive (Vitousek et al. 1997, Grimm et al. 2000). The Long-term Ecological Research (LTER) Network has played a fundamental role in this disciplinary evolution by emphasizing pluralism (McIntosh 1987) through a combination of collaborative, interdisciplinary, long-term, observational and experimental approaches (Hobbie et al. 2003) across a wide array of ecosystems (Hobbie 2003). As a result, LTER science has shown repeatedly how this pluralistic approach yields an unbiased body of knowledge about complex systems that can be, and often is, applied directly to management issues (Pringle and Collins 2004).

The global human population will continue to expand over the next few decades (Lutz et al. 2001, Cohen 2003) and place additional demands on functioning ecosystems (Daily et al. 2000). These demands will require ecological science to continue to generate the fundamental knowledge needed to understand and manage the biosphere (Lubchenco et al. 1991, Palmer et al. 2004). In this context, several recent planning activities have identified a number of Ecological Grand Challenges for the coming century (e.g., NSF 2000, NRC 2000, 2003). Global climate change, altered biogeochemical cycles, loss of biodiversity, and the impacts of invasive species are only a few of the pressing environmental challenges facing society today. Understanding their impacts and *developing solutions* to these challenges will require strong interdisciplinary partnerships, highly coordinated research networks, powerful information systems, and the development and deployment of new research technologies.

The LTER Network has the potential to meet these research objectives. The National Science Foundation has invested in the LTER Network for the past 25 years. This investment has led to an enormous record of significant scientific accomplishment, a research community of more than 1200 scientists, and the development of a powerful research infrastructure for answering ecological questions. However, we believe that the LTER Network is "underutilized" by the LTER community as well as by the broader ecological research community, educators, managers and policy makers. In effect, the LTER Network has not realized its full potential despite its significant record of scientific achievement. This proposal describes an ambitious **planning activity to develop a new LTER science agenda that when implemented will use the Network to its maximum potential and take LTER science to a higher level of research collaboration, synthesis and integration.** This progressive research agenda will also serve as an essential driver in the LTER Network Office strategic planning activity that is currently

taking place under separate funding. These planning activities, when implemented, will position LTER to better address the ecological challenges that society now faces.

2. How did we get here?

In 1980, NSF began its investment in the LTER program with the establishment of six independent research sites. Since that time, LTER has developed into a premiere national and international research network. Indeed, since 1980, the LTER program has expanded its focus from an initial goal of understanding long-term patterns in different ecosystems to a more coordinated attempt to understand similarities and differences in ecological processes common across ecosystems. Through focused research efforts, the LTER sites have accumulated an impressive amount of site-based ecological understanding (Franklin et al. 1990). At the same time, the collection of LTER sites has grown progressively into a research network that now acts as a broadly-based and diverse research platform. Over the 25 year history of LTER, the Network has significantly increased the types of ecosystems examined by expanding the focus of existing sites and through the addition of new sites. As examples of the increased scope, LTER research has documented the importance of land-use history (e.g., Foster and Aber 2003), the effects of natural and anthropogenic legacies on ecological pattern and process (Magnuson 1990, Harding et al. 1998, Moorhead et al. 1999), and greatly increased its focus on coupled human-natural systems (Bennett, et al. 1999, Pickett et al. 2001, Hope et al. 2003). The number of cross-site comparisons within the Network is increasing (Gross et al. 2000, Gough et al. 2000, Waide et al. 1999, Knapp and Smith 2001), and powerful collaborations have been developed with non-LTER sites and networks (e.g., Peterson et al. 2001, Huxman et al. 2004), including the international partners (e.g., Magnuson et al. 2000, Knapp et al. submitted). Together, these changes have inspired greater collaboration among US and international scientists and interdisciplinary interactions among the ecological, physical, social and economic sciences. Nevertheless, the primary LTER mission, historically and today, remains the conduct of site-based science to document, analyze and understand short- and long-term ecological processes, patterns and dynamics (Callahan 1984).

In concert with its research activities, the LTER Network has acted as a valuable testbed for the development and deployment of new research technologies. For example, LTER sites have been key players in wireless sensor technology and networks (e.g., http://wireless.oldcolo.com/ and http://sev.lternet.edu/research/SWEETS/index.html). These technologies have the potential to vastly increase the spatial and temporal volume of data being collected. Yet, the need for careful documentation, management and retrieval of ecological data was increasingly recognized long ago as LTER data sets expanded in scope and lengthened in time. In response, the LTER Network Office, in partnership with LTER sites, NCEAS and other organizations, has played a leadership role in the development of cyberinfrastructure for ecology to store, document, preserve, retrieve, share and analyze data (Michener et al. 1997). As cyberinfrastructure capability continues to develop, it will provide an essential backbone for conducting Grand Challenge Research within and beyond the LTER network (Michener and Brunt 200x).

In parallel with its extensive ecological research activities, graduate and undergraduate education have grown to be deep-seated foundations within all LTER research programs.

In doing so, the LTER Network has enriched the education of an entire generation of ecologists. More recently LTER sites have begun to participate in K-12 education through the Schoolyard LTER Program. The Schoolyard LTER activities serve to educate the general public about the value of ecological research, and hopefully they will also help to recruit a diverse and broadly representative future generation of ecologists.

3. Where are we now?

Clearly, long-term, integrated, site-based research will continue to be the essential ingredient in LTER science. However, cross-site research and synthesis activities are an increasing part of the LTER research portfolio. Several multi-site research projects have been generated internally (e.g., LIDET, Gholz et al. 2000), and others were established through two NSF-sponsored LTER cross-site competitions (1995 and 2000). Many of the cross-site projects started with this funding ten years ago continue today through incorporation of these projects into regular site-based activities. Since the mid-1990's, research symposia at annual Coordinating Committee meetings have explored interconnections among LTER site research. In addition to cross-site research, the LTER Network formed a partnership with Oxford University Press to publish site-based and methods-oriented synthesis volumes (to date: Knapp et al. 1998, Robertson et al. 1999, Bowman and Seastedt 2001, Greenland, et al. 2003; with other volumes in preparation). These syntheses provide a means to summarize years of research at a site, and they promote standardized measurement and analysis protocols across the Network. More recently, the LTER All Scientist Meetings have acted as a catalyst for cross-site synthesis and coordination both nationally and internationally.

Many of these activities were stimulated by the LTER Ten Year Review (Risser 1993) which concluded that although, "…intersite comparisons have been conducted …the power of the network of coordinated research sites has not yet been fully realized." A second comprehensive review (Krishtalka 2002) also noted that, "…missing is a clear exposition of what synthesis science LTER should accomplish—what should the scientific focus, niche and priorities of the LTER program be for the next decade? …despite… accomplishments, some of the critical recommendations of the Ten-Year Review for LTER science have yet to be fully realized. The transition from individual site-based research and science projects to a broader, more integrative research platform has not been sufficient to address large-scale, interdisciplinary environmental issues."

In fact, the LTER strategic plan has identified the third decade of LTER science as one of cross-site research and synthesis that will lead to a better understanding of complex environmental problems and result in knowledge that serves science and society. Despite the increase in synthesis and cross-site research that has occurred to date, most such activities have been *ad hoc* and relatively uncoordinated, thus preventing the LTER Network from achieving its full potential. **What is needed then is a coordinated, organized approach to Network-level science, collaboration and synthesis driven from the bottom-up by the LTER research community**. Indeed, this Network-level research agenda will be the primary outcome of our LTER planning activities. Network-level science that addresses Ecological Grand Challenges now is encompassed within the LTER Network's vision, mission, and scientific priorities. To achieve Network-level

science we must also explore improvements in governance and organizational structure, infrastructure needs, and integration with education and policy initiatives *all built around a strong science-driven research agenda*. This proposal describes an action plan to realize this vision.

4. Where are we going?

Through our proposed 24 month planning process, the LTER Network will identify and pursue the appropriate strategy to accelerate its transition from an association of sites driven by local goals and resources to a fully functional Network driven by regional and national research priorities and shared resources. Network-level science will require increased research resources, new technological capabilities, better cyberinfrastructure, a larger pool of participating scientists, perhaps more LTER sites, as well as effective integration of LTER and non-LTER sites and networks. Within the existing LTER Network, strong site-based research will continue to be a priority, but at the same time we must create a mechanism to design, support, and maintain Network-level endeavors, including short- and long-term cross-site research projects, synthesis and analysis activities, and modeling. To do so will require: (1) incentives for sites to conduct synoptic research, synthesize new ideas, and expand their focus to broader geographic regions; (2) accountability of sites to objectives of the Network, and (3) enhanced capability of sites to participate in new LTER research programs.

We emphasize once again that our proposed planning process is built around transforming and advancing LTER research by engaging the broad community of LTER and non-LTER scientists throughout the planning period. Also, we again emphasize that site-based science will continue to be *the* foundation of LTER research activities. Site-based research has been our strongest asset to date and it is the strength of this foundation that has positioned LTER to move to Network-level science. That said, we again note that several recent activities have identified 6-8 Ecological Grand Challenges for the 21st Century (e.g., NSF 2000, NRC 2000, 2003, various NEON workshop reports). The LTER Network has also been engaged in a scientific planning process through two recent Coordinating Committee Meetings and the 2003 All Scientist Meeting (ASM). Not surprisingly, all of these planning activities have derived similar Grand Challenges. This convergence reflects both a general consensus among ecologists concerning the science challenges we face, as well as the active participation of LTER scientists in all these planning processes. These Grand Challenges are national and international in scope. To address them, LTER must add to its portfolio a new set of long-term, regional-, national- and international scale research initiatives. Based on input from the full LTER research community, seven science initiative areas (Box 1) were identified, and workshops were developed for the 2003 ASM. This meeting

Box 1. Initiative Areas from 2003 All-Scientists Meeting

- biodiversity loss
- extinctions & invasions
- altered water and nutrient cycles
- climate change
- coupled Human-Natural ecosystems
- engineered and designed ecosystems
- forecasting landscape change

was attended by more than 700 participants including over 60 representatives from ILTER sites. These workshops produced white papers describing multi-site research questions focused on the topics in Box 1. Following the ASM, the LTER Executive Committee reduced the seven initiative areas into four Grand Challenge Conceptual Domains (Box 2). The LTER Strategic Planning Process will build upon recent CC and ASM planning activities through a Science Task Force, six working groups and a series of workshops (see below). The outcomes will be (1) a specific set of ecological research questions within the four conceptual domains that can best be addressed by the LTER Network, (2) the empirical, theoretical and experimental designs needed to address these questions, and (3) a plan to implement these coordinated, multi-site research activities.

Box 2. Grand Challenge Conceptual Domains. For a more detailed set of questions and objectives see http://lternet.edu/grandchallenges.

- **Alterations in biodiversity** are one of today's most important global environmental challenges, profoundly affecting ecosystem processes and the services they provide. Of particular human and economic impact are the introductions and spread of exotic species and infectious diseases.
- **Altered biogeochemical cycles at multiple spatial scales** are caused directly or indirectly by human perturbations. We must learn how to minimize future degradation and restore altered element cycles and ecosystem functioning where possible.
- **Climate change and climatic variability** of anthropogenic and natural origin are now well documented. The ecological responses to these changes on generational time scales are as yet poorly understood. Of particular interest are the effects of long-term climate fluctuations and trends, as well as the impacts of sudden climate change on ecosystem structure and function.
- **Coupled human-natural ecosystems** include interactions between patterns and processes in biophysical systems and among social groups in human systems which give rise to emergent behaviors within each system. Fundamental questions in coupled human-natural systems thus have evolved far beyond one-dimensional attention to human activity, to considerations of feedbacks, of human design and engineering of ecosystems, of ecosystem goods and services, and of emergent behavior and stability properties of coupled human-biophysical systems.

Ultimately, the LTER Network needs to institute a periodic planning process that addresses possible future scenarios in national priorities, funding levels, international partnerships, and effective collaborations among the many disciplines and institutions that are required to create national and global scale knowledge. Addressing these scenarios will require agile mechanisms for readjusting LTER operations to anticipate and prepare for change. This planning grant proposal is the initial mechanism to transform the current LTER Network into a unique program that can meet the needs of 21st Century Biology; a new level of science that is synthetic, multidisciplinary, multidimensional, scalable, information driven, predictive and model-based, education oriented, technologically adept, and global.

5. How do we get there?

At the onset of the planning process, we want to clearly state that this proposal contains a fairly prescriptive procedure designed to fulfill the three major objectives of this planning activity: development of highly collaborative Network-level science and synthesis, Network-level integration of research and education, and evaluation of LTER governance structure. However, we fully expect that changes in topics, methods, meetings and processes will take place as the planning process plays out. In effect, rather than being

prescriptive, the planning process will remain highly flexible, creativity will be strongly encouraged, and outcomes may change over the planning period. Yet we must start with a fairly clear roadmap in mind to jumpstart the process.

To begin the LTER Strategic Planning process a Science Task Force (STF) will be charged with driving the overall process (Figure 1) to address the three planning objectives described below. The planning grant PI's (three research scientists, an information manager and an education specialist) will become the planning grant Science Task Force. The STF will receive advice and input from an STF Advisory Committee (STF-AC). Membership on the STF-AC will be determined by the LTER Executive Committee following nominations solicited from the broader LTER community. To be widely inclusive, the STF-AC will have approximately 8-10 members, some of whom will be drawn from the LTER Network. Although the majority of the STF-AC will be research scientists, research technology and education specialists will be represented as well. We feel this structure is appropriate because **LTER** Network-level science is the driving force behind our planning activities, but our research agenda must be fully integrated with technological advancements and creative educational opportunities.

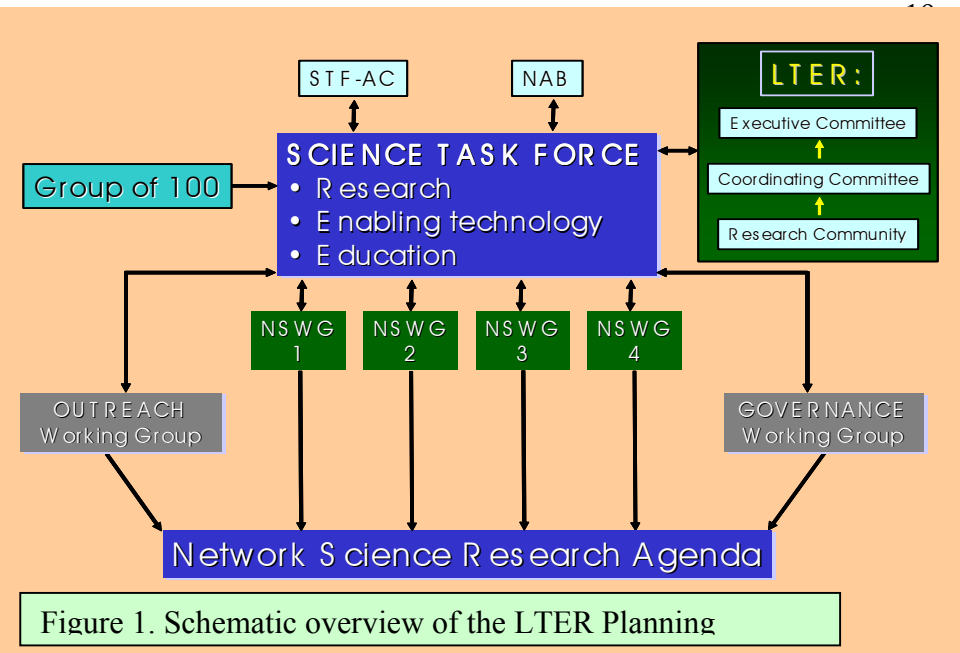


Figure 1. Schematic overview of the LTER Planning

The STF will operate throughout the planning process, meeting up to eight times over the planning period, and will serve as the governing body for all planning activities. Other mechanisms (e.g., conference calls, polycom) will be used to ensure frequent communication among STF members. At the end of the planning period, the STF, in frequent communication with the LTER CC, will take the reports generated by research, outreach and governance working groups and weave them into a comprehensive research and management plan for Network-level science and synthesis that integrates graduate and undergraduate education. Oversight of the STF and the entire planning process will be provided by the LTER Coordinating Committee and the STF-AC. There will be regular reporting and communication between the Chair of the STF and the LTER Coordinating Committee. All interim and final working group documents will be shared with the CC during the planning period so that the network can provide

input and guidance throughout the planning period. Comments will feed back into the Working Group activities. This will provide a direct information linkage between the working groups, STF, LTER Coordinating Committee and the broader LTER community.

The following describes how the STF will oversee the process to achieve our objectives.

A. NETWORK-LEVEL RESEARCH AND SYNTHESIS

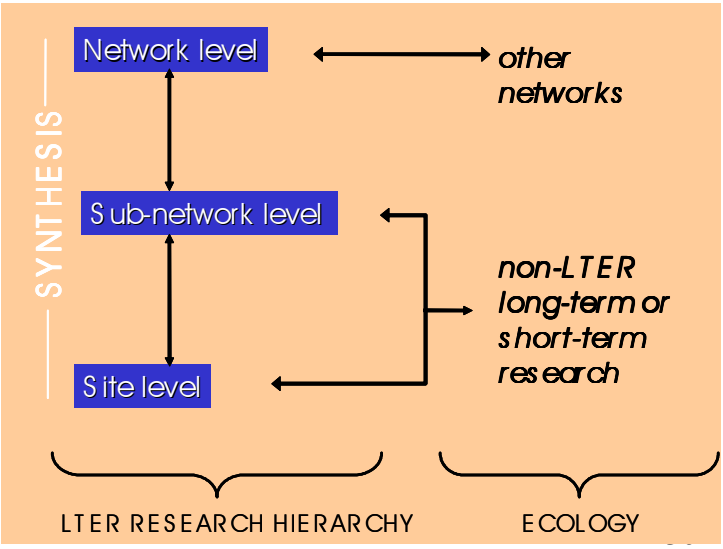
The LTER network has identified multi-site and collaborative research, synthesis and analysis, and modeling as the bases for creative progress in the coming decade. Multi-site and collaborative research includes such activities as doing the same experiments and measurements at multiple sites, and/or single-site research conducted by an interdisciplinary team from within and outside LTER. Synthesis involves many activities (e.g., meta-analyses, modeling), some of which take place within the context of site-based research, others requiring collaboration and cooperation among many sites and scientists. The scientific activities to be developed during the planning process will be long-term, network-level, thematic science; long-term, region-scale thematic science; and shorter-term, Network-scale and cross-site science. As a starting point, these scientific activities will be focused around the four conceptual domains (Box 2) that emerged from the 2003 LTER All-Scientists Meeting: (1) alterations in biodiversity, (2) altered biogeochemical cycles, (3) climate change and climate variability, and (4) coupled human-natural systems. Implementing Network-level science will necessitate adequate research infrastructure (including informatics, technology, modeling and personnel) across the Network as a whole. Finally, the Network must develop linkages and collaborative research with the other networks, organizations, and societies that share our goals of conducting synthetic, large-scale research to address grand research challenges in ecology. **Objective 1, therefore, is to establish activities that will lead to multi-site, highly collaborative and integrated research initiatives that explicitly include synthesis components and, where appropriate, will be coupled with novel training opportunities in graduate and undergraduate education.**

The Network-level research agenda will continue to be developed by a broad base of scientists from inside and outside LTER, including ILTER participants. The initial step in this process will be a five-day meeting of 100 LTER and non-LTER scientists that will harness the creativity existing within the ecological community for the planning process. Membership will be determined by the STF following nominations from the LTER community and other sources including CUAHSI, OBFS, NEON, and other relevant networks. The primary product of this workshop will be a refined set of Network-level research and synthesis activities that will be translated into specific research projects through further workshop activities (see below). This initial "Group of 100" will provide another important opportunity for broad-based input from a wide range of scientific perspectives and individuals, and it will serve as **the first step in a two year planning process whose goal is to derive a detailed research plan built around a set of Grand Challenge research questions that will transform the LTER sites into a fully integrated research network.** The STF will use the recommendations from this meeting as input for the next phase of the planning process that will focus the Grand Challenge research questions to those that the LTER Network is uniquely suited to address and

establish four Network Science Working Groups (NSWG's) that will generate specific research projects and their implementation plans, including research design and an assessment of technology and resources needed to answer these questions. Full implementation of these research plans will transform LTER research to Network-level science and synthesis.

By necessity the NSWG's will be relatively small, comprised of 10-12 core members including LTER and non-LTER scientists, and information management and education specialists, along with supporting members who revolve in and out of the group for shorter time frames to provide specific expertise and input as needed. Membership on the NSWG's will be drawn from various sources including the Group of 100. The STF will recruit a leader for each NSWG based on nominations from the Group of 100 and the LTER CC. Each group leader will be involved in selecting and recruiting working group members. Once established, NSWG's will be funded for the planning grant period and each will meet up to five times. At least once each year, meetings of all NSWG's will be co-located and occur concurrently to insure maximum integration and communication among them. There will also be frequent communication between NSWG's and the STF, the LTER Executive and Coordinating Committees, the NAB and NSF.

It is vital that planning for information management, technical infrastructure and education from a Network perspective be articulated in concert with the development of specific synthetic research programs and themes, as it is the research goals that ultimately define the functional needs for new Network infrastructure. To ensure a dialog between the more centralized infrastructural planning and the research teams, each NSWG will either contain individuals with backgrounds in disciplines such as information management, sensor technology, and graduate and undergraduate education or solicit input from such individuals so that advanced technological tools and novel training opportunities can be incorporated directly into the planning process.



To enhance creativity and participation, NSWG's will use a mixture of mechanisms, as appropriate, based on successful collaborative and deliberative models, such as the National Research Council (NRC), the National Center for Ecological Analysis and Synthesis (NCEAS), Gordon and Chapman Conferences, and the Santa Fe Institute (SFI). These models include but are not limited to focused groups on research topics with broad disciplinary representation (Gordon- and Chapman-like), a rolling roster of invitees within and among working group meetings (NCEAS-like), free exchange of ideas and

free-lance participants among working groups (SFI-like), and deliberative cross-disciplinary panels that seek input and produce recommendations (NRC-like). Each of the NSWG's will be tasked with developing plans for research at site-, sub-network-, and network-scales (Figure 2). Once Network Science Working Groups and their scientific projects are defined, each will be charged with accomplishing the following activities:

- Conducting a comprehensive review of existing LTER and non-LTER data to assess our current state of knowledge, identify gaps in data sets and needs for additional studies, and inform the design of new science initiatives to better meet the initiative challenges
- Designing new experiments and syntheses within the conceptual domains in Box 2. Both thematic experiments (e.g.., consequences of sea level rise, species loss, etc.), regional-scale synthetic activities (e.g.., issues critical to New England or catchments across the Mountain West), and Network-scale synthetic activities will be designed to involve consortia of LTER and non-LTER sites.
- Identifying the necessary new disciplines that must be incorporated into the LTER Network and the enabling technologies and cyber-infrastructure required to accomplish the new science initiatives.
- Incorporating a fully integrated graduate and undergraduate educational program within the science initiatives.

Network-level research and synthesis will create significant information management challenges for the current LTER sites. Although the LTER Network and its partners have become leaders in development of cyberinfrastructure for ecological research, building an informatics system for Network-level science and synthesis (Baker et al. 1999, Brunt et al. 2002, Porter and Stafford 2002) will be a daunting challenge. Metadata catalogs and data access systems that scale to the network level are only now being developed (McCartney and Jones 2002). Increased cross-disciplinary research will challenge information systems to better document and process the semantic meaning behind observations. Dense, wireless sensor networks will likely produce volumes of data that exceed current management capacities (ASM Wireless Sensor Array report).

Disciplinary breadth and technical expertise are distributed unevenly across the LTER Network, which can be an impediment to cross-site synthesis. To provide sites with the opportunity to participate fully in the new science initiatives, mechanisms must be articulated to ensure access to disciplinary expertise across the Network, while at the same time making optimal use of the economies of scale to concentrate resources. The LTER Network Information System Advisory Committee (NISAC) will be charged with evaluating current information capabilities (i.e., collecting existing site self-assessments and developing new assessments as needed) and assessing existing LTER IT infrastructure and research opportunities to determine how well these facilitate LTER research and synthesis goals. Working together with the Science Task Force, NISAC will evaluate site-, regional-, and Network-level infrastructure models that will support and facilitate goals of synthetic research conducted at various levels across the network.

Numerous non-LTER sites (e.g., national labs, NERR sites, ILTER's, OBFS and NAML sites) and datasets exist that are vital to fully achieve Network-level science and synthesis. The AIBS IBRCS activity has identified many sites and networks as part of

the NEON planning process. International LTER sites will be key players, as well. We view these sites and their datasets as important research partners and will make every effort to include them in Network-organized research and synthesis activities. In fact, we anticipate that non-LTER sites will play pivotal or even leadership roles in some synthetic scientific activities and, as such, non-LTER representatives will be leaders in aspects of the planning process. Given that these new activities will place significant demands on time, we believe one way to broaden the talent base for long-term ecological research is through collaboration with individuals and networks outside of LTER.

The long history of graduate and undergraduate training within the LTER Network is a significant success story. In addition to typical university-based training, many LTER sites are involved in NSF-funded IGERT programs, and serve as hosts for UMEB and REU Sites activities. All LTER sites annually support student research through REU supplements. However, these activities are generally site-based and unevenly distributed across the Network. We believe however that our transformation to Network-level science will create unique training opportunities that can meet the goals of NSF's IGERT and REU Sites programs.

According to the RFP's, "IGERT is intended to catalyze a cultural change in graduate education…by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries." The REU program seeks to, "expand student participation in all kinds of research…disciplinary, interdisciplinary, or educational…encompassing efforts by individual investigators, groups, centers, national facilities…" Both programs are intended to, "facilitate greater diversity in student participation…and to contribute to the development of a diverse, globally-engaged science… workforce." We believe that Network-level LTER science and synthesis will create a distributed education platform that is uniquely suited for innovative graduate and undergraduate training that meets the goals of the IGERT, UMEB and REU Sites initiatives. For example, complementary graduate and REU student projects could be integrated across sites and mentors to provide a unique collaborative research experience. Thus, the NSWG's will explicitly incorporate Network-level graduate and undergraduate education and training into their research plans.

B. GOVERNANCE AND COLLABORATION

Although the number of LTER sites has increased, and individual LTER research programs have grown in complexity, LTER governance structure has changed little over time. With the addition of a complex Network-scale science initiative, the governance structure of the LTER Network may need to be redesigned to meet the challenges of an enlarging network, emerging national initiatives, and multiple opportunities to reshape and expand LTER science. Through a Governance Working Group (Figure 1), the LTER Network will examine alternative governance structures and perhaps make a transition to a structure deemed more suitable to its present and future needs. In addition to governance issues, Network-level science and synthesis will require considerable improvements in the culture of collaboration. Therefore, **Objective 2 is to evaluate**

existing LTER Network governance structure and further stimulate the culture of collaboration within the LTER Network.

Governance: Clearly, if the future of LTER science remains primarily site-based, alternative governance models, relative to existing network operations may not be warranted. However, if coordinated, synthetic network-wide science is a major component of an expanding LTER research enterprise, alternate governance structures might be required. Our identification of the scientific challenges that we intend to address and for which we are planning motivates the consideration of alternative governance systems for LTER addressed in this proposal. Moreover, the Network will likely grow over the next few years. Therefore, we need to address the question, "What governance system would be required for a network of 40 LTER sites that also serves the network-wide science mission?"

To accomplish this objective, a Governance Working Group will be established by the STF following nominations by the LTER CC and NAB. Its mission will be to: (1) evaluate the strengths and weaknesses of the present LTER Network governance system, (2) identify models of governance suitable for the LTER enterprise at its current size, for an expanded number of sites, and for an enterprise engaged in system-wide, cross-site science, (3) assess the merits of each model, evaluate alternatives and determine which governance system best serves the objective of moving the network of sites from its current state to a more coordinated program that fosters the science articulated in our grand challenges, (4) suggest a plan to implement whatever changes are needed, if any, and revise the bylaws to accommodate these changes.

Collaboration: LTER, in its conception and maturation, has broken new ground in cooperative, interdisciplinary science and putting aside strong competitive instincts among scientists. Within the LTER Network cooperation among sites is highly valued. Despite these successes, social scientists have determined that ecology is not "collaboration ready" in terms of its technical infrastructure or social environment (Olson and Olson 2000). The cultural changes and technological research needed to "scale-up" the practice of ecology have been well articulated (e.g., Maier et al. 2000, PCAST 1998, Withey et al. 2002). Although activities are underway to develop computational tools to facilitate data integration and analysis and to revolutionize the technical capacity for collaboration in ecology, social relationships between the diverse members of a collaboration, the degree of shared practice, and enabling interactions between people and technology are as important as technical infrastructure in realizing scientific gains (Brown and Duguid 2001, Finholt 2002, Kling et al. 2000, Olson and Olson, 2000).

As noted above, the LTER Twenty-Year Review (Krishtalka 2002) stated that "the LTER program should become a research collaboratory, namely a seamless, integrated continuum from site-specific to cross-site to network- and systems-level ecological research" (p. 3). However, the move toward larger-scale data sharing, aggregation, and synthesis brings with it a greater need for knowledge of effective organizational practices. Thus, social scientists with knowledge of collaborative work and experience working with ecologists will be key participants in our planning process.

Social scientists have studied how current collaboratory projects have attempted to surmount social barriers using adaptive organizational designs, innovative incentive structures, and modern communication technologies. For example, the Science of Collaboratories (SOC) project (http://www.scienceofcollaboratories.org), a 5-year study funded by NSF, is investigating large-scale, collaborative research projects across many disciplines. SOC researchers have cataloged the challenges faced by organizations and individuals participating in distributed group work, and they have uncovered best practices in areas such as data sharing, authorship, and intellectual property. Because social factors are key to collaboratory success, more and more cooperative research ventures are including sociologists, historians, psychologists, and information scientists as members of their project teams.

An SOC project scientist will guide our efforts to discover and evaluate collaboratory governance models, identify and develop best practices and policies, recommend strategies for effective communication, and relate methods used by other collaboratories to design, deploy, and support new technology. The goal of this participation will be to help the LTER Network implement an organizational design and governance structure and select technologies for communication and collaboration that match the culture of the field while enabling the Network to achieve its scientific goals, contribute to a transformation in the practice of ecology, and educate the next generation of scientists.

C. K-12 EDUCATION, OUTREACH AND TRAINING

Objective 3 our planning process will be to envision and develop education and training activities that will infuse LTER science into the K-12 science curriculum. Essentially, we have the opportunity to establish within the LTER Program an ambitious and innovative form of linkage between research and K-12 education. Such a linkage is being promoted nationwide – by NSF, science agencies, academic leaders and others. Within LTER, linking research with education will involve programs where education has intellectual depth, is itself inquiry-based, and contributes to the scholarly fields of teaching and learning. Fortunately, scholarly work in education can occur while helping to guide and provide education and outreach programs to students, teachers and the public. In exploring the interface between education research, long-term ecological research and ecology education, we need to identify the big questions that are important, challenging and intellectually rich, and that the LTER Program and sites are either well- or uniquely-poised to answer. Possible questions include: (1) What are the key ecological concepts, processes and phenomena that people should learn through long-term, data-based and/or synthetic inquiry? (2) How do people best learn these key concepts and research processes? (3) What evidence will we accept that learning has taken place and how can we collect it? (4) What is the long-term impact of ecology education on the diverse audiences it reaches?

An Education, Outreach, and Training (EOT) Working Group (Figure 1), including education coordinators and researchers, will be formed by the STF following nominations from the LTER CC, NAB and Education Committee. The EOT will discuss the benefits and challenges to linking research and education beyond the site-level. Because of the diversity of education programs across LTER sites, three subgroups (K-12, teacher

professional development, public outreach) will be created to focus on objectives already identified by the LTER Education Committee's strategic planning process, including: (1) improving the understanding and appreciation of long-term, large-scale ecological processes by K-12 students through innovative and unique programs and materials for teaching and training; (2) developing the intellectual underpinnings for teaching and learning with long-term, data-based and cross-site inquiry in ecology; and, (3) developing LTER education as a model program to improve science literacy. *Throughout this process, we will explicitly build plans to enhance the diversity of future generations of ecologists and educators involved in long-term ecology research and education.* To begin the process of achieving these objectives the groups will focus on the following tasks, which relate specifically to network-wide education issues:

- Identify synthetic, integrative, or cross-site themes around which curriculum materials can be developed,
- Create a plan to increase participation in ecological research by members of underrepresented groups,
- Carry out a cross-site assessment of Schoolyard LTER programs,
- Identify opportunities for scholarly education research projects that cross individual sites (e.g., cognition, systems analysis, educational reform), and
- Develop long-term measurements and experiments that contribute to curriculum development and provide reciprocal value to research.

Although we will focus primarily on further development of the LTER Schoolyard programs during the planning process, the LTER Network will also begin to address mechanisms to better communicate the results of LTER science to managers and policy makers. Indeed, synthetic science is needed by numerous stakeholders and decision-makers. During the planning process we will design two activities that will enhance the communication skills of interested LTER scientists to policy makers and the public.

The first activity will be a prototype 'outreach' training workshop modeled on the Aldo Leopold Leadership Program but tailored to the LTER community to teach LTER scientists how (and when) to communicate with policymakers, managers, and members of the media. This would entail convening a dozen or so LTER scientists who already have extensive experience working with local policymakers and managers. These scientists would distill the lessons learned and develop a framework for an annual one-week workshop that would become a regular offering within the LTER network. This group will identify potential trainers and engage them in workshop development.

The second activity will be to identify existing occasions for scientists to interact with policymakers and to develop a plan for mobilizing LTER scientists to engage in those opportunities. There are several existing opportunities for scientists to meet with policymakers (e.g., Environmental Institutes, ESA/AIBS outreach projects) through state or federal agencies, through NGO's, etc. During the planning process, these opportunities will be identified for all locales in which there are LTER sites and for national-level programs as well. Those that appear to be the best fit for LTER scientists will be identified, and a plan will be developed for mobilizing scientists to participate, perhaps after attending the outreach training workshop described above.

II. BROADER IMPACTS

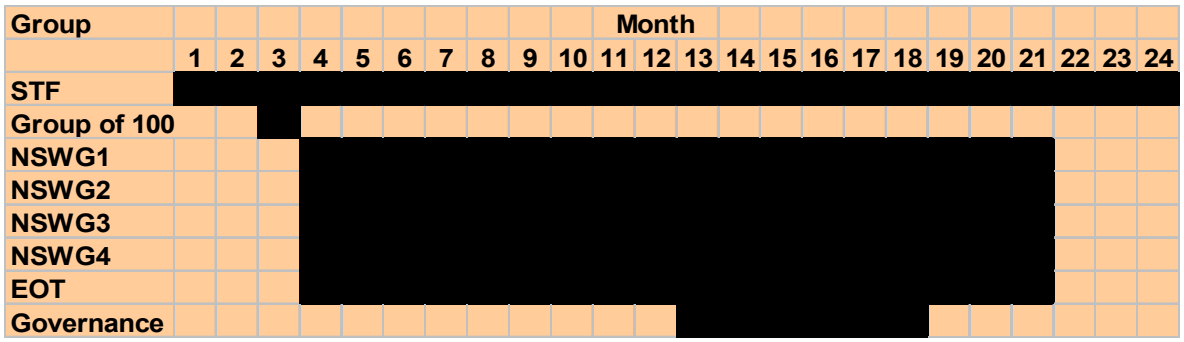
The broader impacts of this activity should be evident throughout this proposed endeavor. Our goal is to develop and implement a new science agenda that will use the LTER Network to its maximum potential and take LTER research and education to a higher level of collaboration, synthesis and integration. We will accomplish this goal by developing a research program built around a set of Grand Challenge Research questions that will uniquely integrate Network-level research with a distributed IGERT/REU Sites model for graduate and undergraduate education and training. The result will be a research program that can best address Grand Challenge Research questions while providing novel education and training opportunities for the next generation of ecologists.

Relationship to NEON. Although similar in topic and underlying goals, the LTER planning activities are not designed to replicate NEON which ultimately will be greater in complexity, scope and spatial extent than the existing LTER network. Rather, our planning endeavor will compliment, enhance and hopefully advance the development of NEON. NEON will take several years to become fully operational yet the ecological challenges facing society are already pressing and immediate. Unlike NEON, LTER already has a well-established network of research sites, considerable research infrastructure already in place, a history of conducting integrated ecological research and a vast array of well-documented long-term data sets. Network coordination and cross-site potential already exist both nationally and internationally. Our open access data policy facilitates synthesis, we have a wealth of information management expertise, and we share a set of common core areas and scientific questions that facilitate multi-site comparisons. Therefore, it is imperative that we start now to build upon our solid foundation of long-term site-based science to create a fully integrated and operational research network.

The LTER Network in partnership with other sites and networks is ideally suited to tackle many Grand Challenge research questions. As these questions evolve and addressing them becomes more complex, LTER science must continue to mature and adopt novel approaches to become the knowledge-based, solution-oriented science that society demands (Lubchenco 1998, Palmer et al. 2004). This endeavor will require enhanced interdisciplinary collaborations and development of an expanded portfolio of research mechanisms built around strong site-based science for which LTER is well known coupled with coordinated multi-site experimental and observational studies, synthesis and modeling. The planning process described in this proposal is designed to transform the LTER sites into a fully operational network that can tackle the Ecological Grand Challenges that face our society now and in the future.

III. Timeframe and Milestones

The following timeline provides a framework for the tasks we will accomplish during the two-year planning activity. Periodic reviews of goals and progress by the STF-AC will direct changes in the timeline that might be necessary as the various activities unfold.



The Science Task Force (STF) will be established immediately upon funding of this proposal. As soon as possible, the STF will solicit names from the broader ecological community to organize the Group of 100 meeting that will refine the research agenda built around the Grand Challenge Conceptual Domains (Box 2) created through prior planning activities and the 2003 LTER ASM. At the same time, the STF will begin to form the four thematic Network Science Working Groups (NSWG's), one for each Grand Challenge Conceptual Domains, drawing on recommendations from the LTER CC and Group of 100. Output from the Group of 100 meeting will feed into the NSWG's. Each NSWG will meet up to five times over an 18 month period to devise specific and detailed research plans for site-, sub-network and network-level science. Graduate and undergraduate research and training will be fully embedded in this new research agenda. The STF will integrate the assessment of current LTER information technology by the NIS Advisory Committee with the technology needs identified by the NSWG's into a plan for cyberinfrastructure to support the network science research agenda.

In month 4, the STF will also establish an Education, Outreach and Training (EOT) Working Group that will also meet up to five times over an 18 month period. This group will specifically address Schoolyard LTER activities and development, and start to develop ideas for stronger outreach to managers, policy makers, and the general public.

At the start of year 2, the STF will convene a Governance Working Group that will evaluate current LTER governance structure and suggest changes, as needed to facilitate Network-level science and education. We believe this working group should not meet until later in the process when the Network-level research agenda is better defined. Scheduling of this working group, however, can be easily modified if necessary.

All working groups will complete their activities by month 21 so that their reports can be synthesized by the STF into a network science research agenda by the end of the 24 month planning period. Ideally, this agenda will serve as the basis for the development of at least one integrated research and education proposal to the NSF LTER Program to implement our new, synthetic, network-level long-term ecological research and training activities, The actual number and kinds of proposals to be submitted, however, ultimately will be determined based on recommendations from the planning process and extensive discussions by the broader LTER community.

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