

Report of the Task Force to evaluate approaches for implementing the network level activities of the Long-Term Ecological Research Network

Statement of Task: The overall goal of the Task Force was to develop findings and recommendations pertinent to the Next Generation of the LTER Network Office (NG-LNO), with particular attention to potential future developments in information technology. The specific objectives were to:

- 1) Consider the potential range of network-level services and activities and recommend general approaches and priorities for the future;
- 2) Solicit input from a broad range of current and potential constituents of the LTER program, including educators and professionals involved in resource management and environmental change adaptation;
- 3) Examine examples of other scientific network offices to identify successful models and useful innovations.

A. Introduction and Background

The Long-Term Ecological Research (LTER) program of the National Science Foundation was initiated in 1980 with eight research projects located across the United States. Thirty-four years on, the number of LTER projects has increased to 25 and spans a broad range of biomes and land-uses, from forests and prairies to coastal, Antarctic, and urban sites. Across all sites, however, a focus on five LTER core areas (primary productivity, population dynamics, organic matter cycles, biogeochemistry of inorganic nutrients, disturbance) ensures that results can be synthesized across the LTER network, leading to new scientific frameworks and theories. LTER projects not only have advanced understanding of ecosystem processes occurring at each site and its associated region, but also have yielded many new theoretical insights that are applicable across diverse ecosystems. The ecological community has been enhanced as more and more investigators consider ecological processes at a wider range of temporal and spatial scales. The educational experience of many ecologists trained over the past 30 years has been broadened through their interactions with the LTER program during their undergraduate and graduate careers. These individuals are less inclined to view other ecosystems only through the lens of their own research site.

Coordination among LTER sites to promote cross-site and continental-scale synthesis was first envisioned when the LTER program was founded.¹ Such syntheses have provided and continue to provide research findings that guide environmental policy and management decisions near where individual LTER sites are located, as well as at regional scales and for the U.S. as a whole.

Scientific syntheses and coordination among LTER sites are facilitated by the LTER Network Office (LNO). Since its inception, the LNO has supported: triennial All-Scientists meetings (ASM); focused synthesis activities such as small workshops and training sessions; and regular meetings of the LTER Science Council, Coordinating Committee, Executive Board (EXEC), and Information Managers. For the past decade, the LNO's major focus has been to advance data

¹ Callahan, J. T. 1984. Long-term ecological research. *BioScience* 34: 363-367.

coordination and establish network-wide database standards. Despite the many challenges inherent in this undertaking – including harmonizing different database architectures associated with individual LTER sites and the disparate types of ecological and environmental data being obtained – this work increasingly has provided crucial support of synthesis goals of the LTER scientists and enhanced the utility of LTER datasets for the broader scientific community.

For nearly 20 years, the LNO has been located at the University of New Mexico in Albuquerque, NM. The staffing of the LNO expanded greatly as database development activities became increasingly important. The cooperative agreement between NSF and the current LNO will expire in 2015, and a competition for the NG-LNO is anticipated. In preparation for this opportunity to re-envision and reconfigure the LNO, the NSF convened a Task Force to solicit input from the stakeholder community about the future function and structure of the Next Generation LNO and to examine models used by other network organizations. This report summarizes the findings of the Task Force, which we hope will provide useful information to NSF program officers as they develop the RFP for the competition for the NG-LNO. In parallel, input from the LTER community was provided to NSF by a committee of the Executive Board of the LTER Science Council. Each LTER site contributed comments in response to specific questions that were based on the current activities of the LNO and addressed the internal LTER expectations and desires for NG-LNO functions.

B. Task Force Goals and Activities

The overall goal for this Task Force was to develop options and recommendations for the structure and operation of a NG-LNO. Because of the importance of data management and coordination, we considered potential future developments in Information Technology (IT) throughout our activities. The three specific objectives of the Task Force were to:

- 1) Consider the potential range of network level services and activities and recommend general approaches and priorities for the future;
- 2) Solicit input from a broad range of current and potential constituents of the LTER program, including educators and professionals involved in resource management and environmental change adaptation;
- 3) Examine examples of other scientific networks to identify successful models and useful innovations.

In the context of **Objective 1**, the Task Force examined ways in which the current balance of LNO activities could be adjusted to increase internal and external communication to facilitate development and application of new ecological ideas and ecosystem analysis tools. The interests of current and potential external users of LTER data, revealed through Town Hall meetings and a web-based survey, also were considered in the context of database maintenance and evolution.

C. Summary of information gathering activities

The Task Force met in early June, 2013, and developed a detailed plan for accomplishing the aforementioned objectives. As an outcome of that meeting, a Town Hall meeting was held at the annual meeting of the Ecological Society of America (ESA; Minneapolis, August 4-9, 2013), for which a survey was developed and implemented on the Task Force's website. *At all venues and meetings, the request for input was structured based on talking points developed at the initial June meeting, but also was modified following subsequent input.* Throughout the autumn of 2013, the Task Force held regular conference calls to discuss findings and make further plans. The experience gained at the ESA Town Hall meeting was used to plan a Town Hall meeting at the annual American Geophysical Union (AGU) meeting (San Francisco, December 9-13, 2013). The Task Force met as a whole at NSF in early March, 2014 to discuss recommendations and draft the report. The March 2014 meeting was supported by the participation of Andrea Sojda (NSF-DEB).

Town Halls: The open Town-Hall meetings at the ESA and AGU meetings provided the Task Force with the opportunity to “listen and learn” and to reach out to current LTER scientists and constituents who are not now working at LTER sites and could bring new points of view to the NG-LNO re-envisioning process. The sessions were scheduled to minimally conflict with other high-profile activities and were advertised widely (via social media, flyers, posters, and at section mixers). Background information about the LTER Network was distributed in advance and at the meetings. Both meetings were held in conjunction with a buffet lunch and were well attended: ~40 participants ranging from graduate students to senior investigators.

At both meetings, one focus of the discussion was on how to structure the NG-LNO to maximize inclusiveness, participation, transparency, and data-sharing across the LTER network. The meetings were organized in a manner that was effective at soliciting information from the broader community while respectfully encouraging input from diverse participants. For example, following common protocols for stakeholder group meetings, comments were placed on pages with distinct headings, e.g., Information Management (IM), on the wall during lunch and those comments were aggregated by members of the Task Force to structure the discussion. Further, each attendee introduced themselves and had a name plate that they turned to a vertical position to indicate their intent to comment on a topic. All participants who wanted to voice their comments were thus easily recognized and had an opportunity to do so before a new topic was introduced.

Website and Surveys: The Task Force created a website to disseminate information and solicit additional input. The paper-based survey piloted at the ESA meeting was revised slightly and posted as a SurveyMonkey on the website (Appendix 1). The survey sought information on individuals' familiarity with the LTER Network and the LNO, as well as their ideas and opinions as to what makes for a successful network and coordinating office, both in general and specific to LTER. Information about the survey was distributed at the Town Hall meetings; advertised on relevant list-servers (e.g., all-lter and ecolog-l²); and mentioned in the LTER Newsletter. About 268 responses were received from a wide variety of individuals. Detailed findings from the survey are in Appendix 1.

² <http://www.lsoft.com/scripts/wl.exe?SL1=ECOLOG-L&H=LISTSERV.UMD.EDU>

Site visits: Site visits to learn about network offices included visits to the LNO in Albuquerque (October 2013) and to NEON's office in Boulder (November 2013). The site visit to LNO was focused on Information Technology (IT) and IM, whereas the visit to NEON was broader in scope. At least two members of the Task Force participated in each site visit. The site visits provided valuable insight into day-to-day operations, IT/IM, and approaches for facilitation of network activities.

Interviews: One member of our Task Force (Zimmerman) conducted semi-structured interviews with leaders of six organizations. Five of the organizations were affiliated with the ecological or environmental sciences, whereas one was in a human health discipline. The six organizations differ in intellectual focus from each other and from LTER, but they are all alike in serving dispersed groups that need some coordination and centralized services. They also vary in size (e.g., number of individual or organizational members), budget, governance, and staffing (e.g., all volunteer, combination of paid and volunteer). The objectives of these interviews were to learn about the principles and considerations that guided their organizational structures; the specific programs, functions, and services provided by each organization, particularly its coordinating office (if it had one); and lessons learned. When appropriate, we also asked about an organization's interactions with LTER and/or the LNO.

Outreach to educators: A booth and book-signing event were organized for the Denver regional meeting of the National Science Teachers Association (NSTA) (December 12-14). The booth was staffed by two members of the Task Force (Ebert and McKnight) and by Amy Rinehart, Editor of the LTER Schoolyard Book Series. At NSTA, there was interest in the books and discussions of how the books had been used by teachers who visited the booth, but there was little interest among attendees in discussing the NG-LNO or in completing the Task Force's survey.

D. Criteria for NG-LNO functions and activities

Many interesting and creative ideas and suggestions were brought forward and enthusiastically discussed at the Town Hall meetings and communicated through the survey responses and interviews. The Task Force recognized the need to identify both conceptual and practical criteria to use to help frame its discussions and deliberations regarding NG-LNO roles, responsibilities, functions, and structure. Without such criteria, it would have been difficult to determine what should be within and outside the bounds of key areas of functionality (i.e., communication, IT/IM, facilitation, and synthesis) for the NG-LNO. The Task Force identified the needs for coordination to advance the general mission of the LTER network and then asked, "Among these areas, which ones are most difficult to coordinate?" **We concluded that the functions that are most difficult to coordinate should be the primary foci of a NG-LNO**, and these areas/functions are identified here, i.e., communication, IT, and synthesis. The Task Force continually posed this question as we analyzed all the input received. In addition, we addressed the role of the NG-LNO in educational activities.

Within this context, the Task Force considered what could be achieved more efficiently, effectively, or economically if it were centralized? For example, although best practices for communication might appropriately and ideally be shared through direct networking among

sites, the NG-LNO might provide technical communication infrastructure (e.g., videoconferencing, software) to facilitate this interaction. In addition, while identifying what is difficult to coordinate, the Task Force considered things that cannot realistically be accomplished at the site level or through informal networking between sites. For example, the establishment of common technical standards or protocols is unlikely without network-level policy and coordination. Further, without aggregation and a point of contact at the network level, it would be hard for the LTER Network as a whole to connect and participate with other constituents and organizations.

Another criterion that the Task Force articulated was the notion that the NG-LNO should be a service entity, not a research and development entity. In other words, NG-LNO should not be a 26th LTER site. But being a service entity does not mean that leadership is not important for the NG-LNO. Rather, strong leadership is critical. Further, even in areas where coordination is needed at the Network Office level, community engagement will continue to be a key to success. Community engagement is also important to identify needs for coordination that would offer efficiencies and economies of scale.

Finally, the Task Force noted the importance of branding for the LTER Network with respect to effective communication and outreach, and identified this as an important role for the NG-LNO.

E. Findings and Recommendations for Main Activities of the NG-LNO

The findings and recommendations below are based on the Task Force's synthesis of the diverse input received. We present these findings and recommendations under three main categories that are relevant to activities that could be covered either in one or in separate RFPs for the NG-LNO. In some cases we point out that the findings were based on input received as a result of a particular activity of the Task Force. In general, the recommendations are based on a synthesis of the findings.

1) Communications

Overview. There is much interest across the LTER community in both improving internal communications and expanding external communication of LTER products (see Appendix 2B). Internal communications, which include face-to-face and virtual meetings, the list-servers, the LTER website, and the newsletter, provide some cohesion for the individual researchers and sites that make up the LTER Network and help to define and reinforce the LTER community's internal culture and voice. In contrast, external communications, which involve both formal and informal interactions and engagement, are aimed at the broader scientific community, policy makers, natural resource managers, educators, students of all ages, the media and the general public. These "stakeholders" are the audience for LTER's broader impacts. The LTER Network represents "big science" and "big impacts," which should be an expectation for a program of the size and scale of LTER. Such impacts could be initiated through a consistent and clear LTER "brand." We note that quantitative assessment of such an impact may be inherently challenging.

- Finding 1. The triennial ASM meetings provide an opportunity for introducing new collaborators, post-doctoral fellows, and students to LTER. These regular meetings have provided continuity for groups of scientists who work together on, for example, cross-site syntheses comparing datasets across sites. There was broad consensus of the importance of the ASM among the participants at both the ESA and AGU Town Hall meetings. Furthermore, participation in an ASM introduces new researchers to the LTER community, exposes them to the wide range of LTER science, and embeds them in the LTER culture that values collaboration and exploration of new insights and interdisciplinary research. This underlying LTER culture may not be encountered in its full expression at national meetings of major scientific societies. Finally, interest was expressed in increasing the frequency of the meeting to, for example, every other year instead of every three years; graduate students expressed concern that they would only attend one ASM during their graduate career, and senior scientists associated progress in synthesis endeavors with particular ASMs.
- Finding 2. LTER communications to date have been limited and ineffectual, both internally and externally. Although the network office maintains a website, a list-server, and a newsletter, these do not seem to be viewed as ‘go-to sites’ or ‘must reads’. Yet, LTER has valuable data and insights that could be relevant to a wide range of ecological and environmental issues, and multiple constituencies are interested in using LTER data and learning about what is happening across the network.
- Finding 3. Financial, logistical, and environmental (e.g., carbon footprint) barriers increasingly will constrain face-to-face interactions in the coming decades. Scientists, students, and stakeholders are demanding dynamic, interactive, and effective two-way means of communication. Different people absorb information in different ways, and alternatives to the ASM such as virtual platforms can be useful also.
- Finding 4. Society is demanding that scientific knowledge be co-produced by stakeholders, shared outside the scientific community, and used to solve problems and teach youth the skills and knowledge they need to meet the challenges of the 21st century. The LTER Network has many stories to tell in this regard.
- Finding 5. The Task Force received minimal input from educators through the survey with respect to the Schoolyard LTER program. By hosting a LTER booth at the NSTA regional meeting in Denver, we learned that the LTER children’s book series has achieved recognition among educators in the region where the book series was initiated. Many educators came to the booth to share with us how they had used one or both of the books in their classroom or in their curriculum, and to purchase a signed copy. However, these educators had little interest in providing input to the Task Force on how the NG-LNO might best work with K-12 educators. The LTER children’s book series currently includes only books from about one third of the LTER sites, nonetheless, there was a greater awareness and use of the LTER children’s book series among the LTER survey respondents (20%) than the non-LTER respondents (Appendix 1).

- Recommendation 1: Face-to face internal and external communications remain important and necessary. A continued emphasis should be placed by the NG-LNO on the ASM,

workshops, small group meetings, science exchanges, and face-to-face gatherings. *Facilitating* these interactions should be a central service of the NG-LNO.

- Recommendation 2: In an increasingly connected digital world, it is critical that the NG-LNO keep pace with new media, technology, and social networking tools. A “universal design for learning” approach should be taken, providing information in standard text and prose. The NG-LNO also should develop a strategic portfolio that may include blogs, twitter, photos (e.g., Flickr, Pinterest), video (YouTube), webinars, etc. the NG-LNO should fully understand and embrace these new technologies. The existing LTER Communication Plan should be the starting point for taking the NG-LNO’s communication strategy to a new level.
- Recommendation 3. The LTER Network website and associated networking tools should be the go-to place for people to find information about the results of LTER research, its past and current activities, and network news, and should support two-way communication. Finding products such as reports from LTER-funded workshops should be easy. The NG-LNO also should facilitate sharing of stories by and about the sites and people of LTER, with each other and the wider world. The LTER Network website should serve as repository for the ‘success stories’ for which LTER results have made an impact on land management, public policy, and/or education.
- Recommendation 4. The NG-LNO should help develop, promote, and facilitate the “branding” of LTER and the internal culture of pride, excitement, quality, and cutting-edge science in ecology. An emphasis on science communication and constantly translating LTER science should pervade all levels of LTER communications. The NG-LNO should continue to identify and reach out to multiple constituencies at the federal, state, private, and NGO levels.
- Recommendation 5. The NG-LNO should support the internal communication about the Schoolyard LTER programs at the individual sites and the activities of the LTER Education and Outreach Committee. However, the NG-LNO should not develop a program to organize the products of these activities for use by educators nationwide. Further, the LTER Schoolyard Book Series should not be overseen by the NG-LNO in the near future.

2) Information Technology and Information Management:

- A. Overview.** The expectations for robust IT/IM across the LTER sites have increased over time. These expectations confront the challenges inherent in a network that was started in 1980, before the development of modern IT/IM. In addition, given the different environmental settings, data obtained to address the five LTER core research areas vary within and across sites; these differences are nuanced and need to be well-documented. The LTER Network has been supported over the past several years to meet these challenges through the development of the Provenance Aware Synthesis Tracking Architecture (PASTA) program. PASTA provides the framework and application suite for the LTER data repository. Further background is provided by position paper from the LTER Network Information System Advisory Committee (NISAC) (Appendices 2C and 2D). Table 1 compares the approaches and data usage of LTER with those that are being

implemented by the National Ecological Observatory Network (NEON) and by the Global Lake Ecological Observatory Network. The differences in approach are explained based on the site visit in Appendix 3.

- Finding 1. PASTA appears to be a successful database platform. It has achieved high quality data integration that can be used by both LTER and non-LTER scientists now and in the future. One important feature of PASTA is that it employs a “versioning” approach that is not replicated by many other database/data integration programs and that lead to more useful outcomes from a database searches. This finding is supported by the comments provided by the LTER Network Information System Advisory Committee (NISAC). Furthermore, the LTER respondents to the survey felt than an NG-LNO should play a leadership role in data and IM by providing a centralized data repository, developing data sharing standards, and providing technological tools.
- Finding 2. The successful achievement of PASTA-compliant data by individual LTER sites is a source of pride for their information managers. They value the training that they have received and are eager to advance the use of LTER data beyond the individual site. The information managers are strongly motivated to use PASTA to reach out in an effective way to the non-LTER community.
- Finding 3. There are many diverse users of many LTER data products. In fact, the perception by many non-LTER-affiliated scientists is that the LTER Network’s primary purpose is to provide ecological data, based on their widespread use of LTER data. Some users are associated with other regional research sites, such as field stations, and use the LTER data for informational purposes or to ground-truth and compare with their own data. There also are non-LTER scientists who choose to conduct their own research at LTER sites because they make use of LTER data products that include past and current data.
- Finding 4. The PASTA approach serves LTER and has the potential to be useful to non-LTER scientists. The survey conducted by our Task Force showed that there is great interest, by both LTER and non-LTER scientists, in using LTER data to conduct cross-site comparison and continental syntheses. Further, some of the non-LTER-affiliated attendees at the AGU Town Hall meeting noted that they currently use LTER data to conduct cross-site comparisons. These users are looking forward to integration of even more LTER data into PASTA.
- Finding 5. At the Town Hall session at the AGU meeting, there was great interest on the part of non-LTER scientists in the possibility of integrating their own data, collected at or near LTER sites, into PASTA so that the data would be used by others. In fact, this possibility was particularly attractive to graduate students and post-doctoral scientists who viewed it as a way to increase the visibility and impact of their own research.
- Finding 6. The long-term maintenance of PASTA, including its critical versioning approach, will require dedicated and stable funding and personnel. The staff will need to be tasked with providing support and service to upgrade and maintain PASTA. It is not be feasible to distribute these tasks of maintenance and upgrading among the individual sites.

- Finding 7. The demands for efficient and comprehensive information and technology management will accelerate as data are streamed from diverse sensors into LTER site databases at high frequencies. Greater use of visual imagery to obtain ecological data through the use of satellite imagery and unmanned aerial vehicles (“drones”) will amplify needs for data storage, real-time analysis, and retrieval.
- Finding 8. In all these advanced data sources, the need for clear and well-documented description of provenance and quality assurance methods will continue to be important for any user of LTER data.

- Recommendation 1. Given the successes of the implementation of PASTA, it is critical that PASTA be maintained into the future. The new plan should “carry on” by building on successes of PASTA and integrating IT advances into PASTA.
- Recommendation 2. In the near future, the LTER network will not need to develop a new database platform, but rather should operate in a “technology watch” mode: looking to the frontiers of data management to incorporate those advances into the PASTA framework.
- Recommendation 3. Given the strong interest that was articulated by non-LTER scientists in being able to integrate their data into PASTA, the RFP for the NG-LNO IT/IM functions could include establishing a cost center for incorporating data collected at or near LTER sites into PASTA. These datasets could include data from research programs which are funded by other agencies, such as DOE and NASA.

3.) Synthesis

Overview. Cross-site synthesis of scientific findings is a core goal of many site-based researchers – from graduate students to PIs – and always has been a core goal of the LTER Network. The synthesis of findings across the LTER Network of research sites has contributed to the advancement of ecosystem science and related fields of science as illustrated in Figure 1. The NG-LNO should facilitate such syntheses, manage them to maintain accountability, and communicate them strategically and effectively.

- Finding 1. At both the ESA and AGU Town hall meetings, it was evident that the triennial LTER ASM is highly valued by many individuals for many reasons. One reason the ASM is so valued is that it serves as a locus for ongoing discussions of existing working groups focused on particular cross-site synthesis products. This sentiment also came through in comments from some of the LTER respondents to the survey. The ASM also provides opportunities for structured and unstructured discussions among site researchers that lead to creation of new (sub)networks and working groups among site-based researchers.
- Finding 2. Active working groups are highly valued formats for advancing scientific synthesis and developing a new cohort of young scientists. Support by LNO of small grants for working groups (on the order of \$10K) through rapid funding to students and post-docs has led to cost-effective cross-site syntheses, and promoted a “nimble” grassroots mode of timely and ongoing synthesis that is not otherwise available. These

working groups may meet during the ASM, but they also conduct important analyses in the period between ASMs. Working groups promote not only analysis and synthesis skills among young scientists but also develop leadership skills and provide mentorship to young scientists beyond their immediate academic advisor.

- Finding 3: The NG-LNO could build upon the approach of the current LNO by overseeing the activities of supported working groups in a manner that holds the working groups accountable for their work in an organized and transparent framework. In particular, there is an opportunity to document the findings and disseminate the products of working groups through the NG-LNO website. Internal reports of expenditures, technical reports, and publications could also be managed by the NG-LNO in a more timely and transparent fashion and posted prominently on the NG-LNO website to demonstrate the appropriate level of accountability expected for working groups.
- Finding 4: The synthetic data products from the working groups are rarely accessible within PASTA. Requiring submission of these data products by future working groups represents a great opportunity for advancing LTER synthesis beyond the LTER internal community. This would be especially important in introducing new researchers to the LTER community and exposing them to the wide range of LTER science.
- Finding 5: Outcomes of cross-site syntheses could be communicated in a variety of forms appropriate for different audiences. These include, but are not limited to, peer-reviewed publications, QA/QC'd datasets accessed into PASTA; non-technical white papers, or press releases and media kits.

- Recommendation 1. The ASM serves an important function, and should continue in some form, perhaps more frequently than triennially. Some organization needs to handle logistics and meeting planning in a manner that is not burdensome for the individual LTER sites. The organization providing this service could be the NG-LNO or it could be an outside contractor, e.g., this role could be outsourced if there was some stability in the arrangements.
- Recommendation 2. “mini-ASMs”, perhaps associated with annual national meetings of ESA or AGU, should be encouraged as a cost-effective way to increase the frequency of more formal cross-site contacts. Logistics (e.g., room reservations, coordination with national meeting planners) should be centralized, possibly in the NG-LNO.
- Recommendation 3. Given that working groups are a cost-effective method of cross-site synthesis and development of leadership for the future, an appropriate funding mechanism and funding administrator within the NG-LNO should be identified to ensure that they continue. For some emerging topics, the resources could be expanded to support continued efforts by a graduate student or post-doctoral scientist.
- Recommendation 4. Products from working groups should be publicly accessible in a timely fashion. At a minimum, synthetic datasets should be accessed into PASTA. Working group reports need to be easy to find on the LTER Network website. Publication of synthesis outcomes in the peer-reviewed literature should be encouraged and promoted through press releases and other activities at the level of the NG-LNO.

4.) Education and Outreach

Overview. By implementing long-term educational initiatives, the LTER education program can develop unique approaches to train future researchers and to enhance learning and teaching of ecological concepts. Disseminating this approach through the involvement of graduate and undergraduate students, postdoctoral scientists, other professionals, K-12 educators and students, and the general public can help to ensure the contributions of ecology in the future. The current LNO has regularly held training activities targeted for graduate students and post-doctoral scientists. Each LTER site has an education and outreach program that meets site level goals (Appendix 2A). Thus, the programs vary widely in terms of students reached (e.g. K-12, undergraduate, and graduate students) and adults involved in citizen science. The LTER Schoolyard program is targeted for K-12 students and their teachers. These educational activities build on the theme of the LTER site being a “schoolyard” that can use the uniqueness of the LTER programs to promote training, teaching, and learning about ecological research and Earth’s ecosystems. There is an active education and outreach committee that shares ideas and meets at the ASM, and has regular conference calls, all supported by the LNO (Appendix 2A). Another network level component of the Schoolyard program is the LTER Schoolyard Book Series, which is directed towards elementary students and includes books for seven sites, with several more in development. The Book Series is published by Taylor Trade Publishing, an imprint of Roman & Littlefield Publishers, and is not managed by the LNO. The development of new books is overseen by an Editorial Committee with members from the LTER community. Two planning workshops were held in 2004 and 2011 and the presentations are available on edited DVDs, which are used by prospective authors.

- Finding 1. The LTER schoolyard book series exemplifies the potential for a strong “branding” approach in the area of K-8 educational outreach, which may contribute to broader impacts. This branding approach also exemplifies the challenges in quantitative assessment of impact at the national scale of the LTER program. Several of these books are sold in informal settings, e.g., gift shops at National Parks, to visitors who are interested in ways to share their experiences from their visit with family and friends. The increase in understanding of ecological concepts on the part of children or family members in this context may be difficult to assess. Similarly, the impact of “branding” of LTER communications in other formats in the future may be difficult to assess directly.
- Finding 2. Virtual, face-to-face, or self-paced online training has been and should continue to be part of NG-LNO responsibilities, especially those for graduate students and post-doctoral scientists. This training complements the training that happens in multiple ways at individual sites. How the training is accomplished can vary and can be determined by the NG-LNO. For example, they may contract with outside trainers for some things and use individuals from across the LTER network, including NG-LNO staff, for others.

- Recommendation 1. Undergraduate and graduate students and postdoctoral scientists should be the NG-LNO’s highest priority for education, outreach, and training. The NG-

LNO should coordinate or offer training at a Network level based on identified needs (e.g., at the annual graduate student workshop) in areas such as IT/IM, GIS, and sensor networks. In keeping with our overall principle, the training offered by the NG-LNO should be in areas that they can do most efficiently and are of broad need in the Network.

- Recommendation 2. The NG-LNO should support the meetings and communications of the network level education and outreach committee in a manner similar to the support provided to other LTER working groups.

F. Reporting and Structure

The Task Force recognizes that there are different possible administrative structures for the NG-LNO. For example, the NG-LNO could be located in a single location, with fixed offices, staff, and an executive director. Alternatively, the NG-LNO could be distributed, with satellite offices responsible for IM/IT, communications and outreach, or facilitating synthesis. The director of a distributed NG-LNO could be based at one of these three satellite offices, or s/he could be at a fourth location. Another alternative is that the director of a distributed NG-LNO could be the chair of the LTER-EXEC rather than an independent executive director, but this model would represent a large commitment on the part of the chair and presents some difficulties with regards to continuity and potential conflict-of-interest, depending on the reporting structure of the NG-LNO (see below). There are undoubtedly other possible models, and the Task Force does not recommend any particular model. What is most important is that the RFP either delineate acceptable models or clearly ask proposers to describe their plan for managing the NG-LNO.

With regards to the structures for continuation of PASTA, the Task Force recognizes several possible approaches: 1) keep PASTA within NG-LNO, including the maintenance of PASTA in an over-arching RFP for the NG-LNO; 2) separate responsibility for PASTA into another award and RFP (a potential outcome of this option could be that NSF and other partner agencies, e.g., USDA-FS ERFs, USGS, NOAA, independently support and maintain PASTA); 3) spinning-off PASTA as a stand-alone company, either as a non-profit or for-profit company; 4) contracting with an existing DBMS company to maintain PASTA; or 5) selling it outright to an existing DBMS company, with some provisions for maintenance over at least a decade. The latter three of options entail additional, unstudied risks for the LTER program. In all cases, however, a relationship with the overall network information system (NIS) of the LTER Network and some continued training of information managers at the sites will continue to be necessary and a means to integrate related non-LTER data would be desirable.

Whichever of these approaches are chosen for the structure of the NG-LNO and PASTA, the Task Force recommends strongly that a clear reporting structure be established among the NG-LNO, the LTER-EXEC and NSF. The Task Force recommends that NG-LNO should report directly to NSF, and that LTER-EXEC act in an advisory capacity to NG-LNO with regard to, for example, implementing the Strategic and Implementation Plan for the LTER Network or overseeing synthesis working groups.

The Task Force also recommends that regardless of the administrative structure of the NG-LNO that there should be in place – at the time of awarding the NG-LNO cooperative agreement – a

clear transition plan that addresses: 1) Seamless, uninterrupted operation and continued maintenance of PASTA; 2) Reference to, continued use of, and evolution of the LTER Network Strategic and Implementation Plan; 3) Consideration and planning for succession and change of leadership.

G. Summary and conclusions

We conclude that enhanced communication, particularly external communication, but also internal communication, is a critical function for the NG-LNO. External communication will need to have informative and engaging content, be timely and employ diverse modern approaches. Embracing the dynamic and varied nature of communication will be important to the success of the NG-LNO.

The NG-LNO should continue to provide coordination and play a leadership role in developing community-wide standards for cyber-infrastructure, data management, and transparency in ecological and environmental research and practice. It is important for the overall success of the LTER Network that some entity maintains PASTA and continues to constructively engage with the information managers at all the LTER sites. Although PASTA may not be the only database management system with its particular features, including EML/XML compliance testing and version control, these remain challenging problems for software engineers. We caution against undervaluing the costs of operation and maintenance of these and other key features of PASTA.

We emphasize the importance of synthesis in fulfilling the role of the LTER network as a generator of new broad scale scientific concepts and theories. The NG-LNO should continue the “All Scientists”-style meetings, and study/implement means to increase the frequency of meetings of active working groups (perhaps in association with national conferences of other scientific societies). Cross-site projects are highly valued, effectively engage young scientists, and help forge connections across fields.

Many models for organizing the NG-LNO may be effective, and the Task Force does not recommend any particular model. We do note that the approach of splitting the RFP into two parts – IT/IM and synthesis and communication – may be a cost-effective option. Finally, if the NG-LNO is to achieve these goals, sufficient resources must be available.

Task Force Members: This NG-LNO Task Force included individuals with broad backgrounds in understanding and implementing interdisciplinary environmental science programs within research institutions, mission-oriented agencies, and national and international LTER sites and environmental observation platforms.

Diane McKnight is a professor in Civil, Environmental and Architectural Engineering and a Fellow of INSTAAR at the University of Colorado. She is the lead PI of the McMurdo Dry Valleys LTER project, a co-PI of the Niwot Ridge LTER project, and Chair of the Editorial Committee of the LTER Schoolyard Children's Book Series. From 1979 through 1996, she was a research hydrologist with the U.S. Geological Survey, and participated in designing the National Water Quality Assessment Program. She is a Past-President of the American Society of Limnology and Oceanography and the Biogeosciences Section of the American Geophysical Union (AGU), and brings experience in organizing interdisciplinary research communities. Diane is the founding Editor of the Journal of Geophysical Research-Biogeosciences, a Fellow of AGU and AAAS, and a member of the National Academy of Engineering.

Aaron Ellison is the Senior Research Fellow in Ecology at the Harvard Forest, and co-PI since 2006 of the Harvard Forest LTER project. He brings to the committee extensive experience in ecological research, statistics, data management and cyber-infrastructure development, and he was a member of the internal LTER visioning committee for the next-generation LTER network office. Aaron currently serves as the Editor-in-Chief of *Ecological Monographs* and is a Fellow of the Ecological Society of America.

Christine Goodale is an Associate Professor in Ecology and Evolutionary Biology at Cornell University. She is a recent co-PI at the Hubbard Brook LTER. Her service includes activity on the NEON Science, Technology, and Education Advisory Committee (STEAC) since 2008, past associate editorships at *Ecosystems* and *JGR_Biogeosciences*, and past secretary of the ESA Biogeosciences section. She currently directs an IGERT graduate training program at Cornell in Cross-Scale Biogeochemistry and Climate.

Margaret Palmer is the Director of the National Socio-Environmental Synthesis Center and a professor in the Department of Entomology at the University of Maryland and a past-Director and current professor at the Chesapeake Biological Laboratory of the University of Maryland Center for Environmental Science. She has also has extensive experience as Director of the Ecology Program at NSF from 1999-2000. She is an Aldo Leopold Leadership Fellow and a AAAS Fellow, and has received the Distinguished Service Award of the Ecological Society of America.

Lindsey Rustad is a Research Ecologist with the US Forest Service and Forest Service Team Leader for the Hubbard Brook Experimental Forest. She has been the lead of several national and international research coordination networks, and brings to the committee over 25 years of experience in biogeochemistry, forest ecology, and, more recently, advanced sensor networks.

Ann Zimmerman is an independent consultant specializing in program planning and evaluation for science and technology. She brings more than 25 years of experience as an information specialist, social science researcher, and evaluator working with scientific researchers and

organizations. Prior to starting her own company, Ann was a member of the University of Michigan's School of Information where her research focused on scientific collaboration, interdisciplinary research, virtual organizations, and the influence of new technologies on the practice and organization of science. Before obtaining her doctorate, Ann worked with fisheries scientists, wildlife biologists, and other environmental researchers during a long career as an information manager at two federal scientific research centers. She has been actively involved in several important scientific initiatives and led the Governance Working Group for the LTER Network planning process and was a member of the National Ecological Observatory Network Design Consortium.

Jessica Ebert- Is a Ph.D. student in Civil, Environmental and Architectural Engineering and at INSTAAR at the University of Colorado. She is conducting part of her thesis research studying biogeochemical processes in lakes as part of the MCMLTER.

Appendix 1. Survey Report

Appendix 2. Contributions from LTER committees

- A. LNO support of goals identified by the Education and Outreach Committee as key to development of the LTER Schoolyard Program (sLTER) and LTER higher education initiatives
- B. Letter to Task Force from The LTER Communication Committee
- C. Cover letter for LTER Network Information System Advisory Committee (NISAC) position paper
- D. LTER Network Information System Advisory Committee (NISAC) position paper

Appendix 3. Report from NEON Site Visit

	NEON	LTER	GLEON
Approach	Data driven	Hypothesis driven	Hypothesis driven
Data Acquisition	Integrated, top-down, highly calibrated data collection system, with strict control on sensors and protocols	More diverse approach to data collection techniques; but with common QC and meta-data standards.	Very diverse approach to data collection; participation is voluntary; limited control on qc and meta data standards
Data delivery	Single web portal; limited interpretation	Central web portal (PASTA) as well as multiple site portals, with robust interpretation and outreach	Site based web portals
Data History	Current and future	Past, current and future (historical data are a key defining feature)	Past, current, and future. Future is less secure due to less secure funding.
End Users	Broadly defined as the ecological community	Broadly defined as the ecological community, but also more targeted site-specific community of scientists	Specific to GLEON network

Table 1: Differences in approach, data usage and delivery across three ecological networks. NEON- National Ecological Observatory Network (www.neoninc.org), LTER, and Global Lake Ecological Observatory Network (<http://www.gleon.org/>).

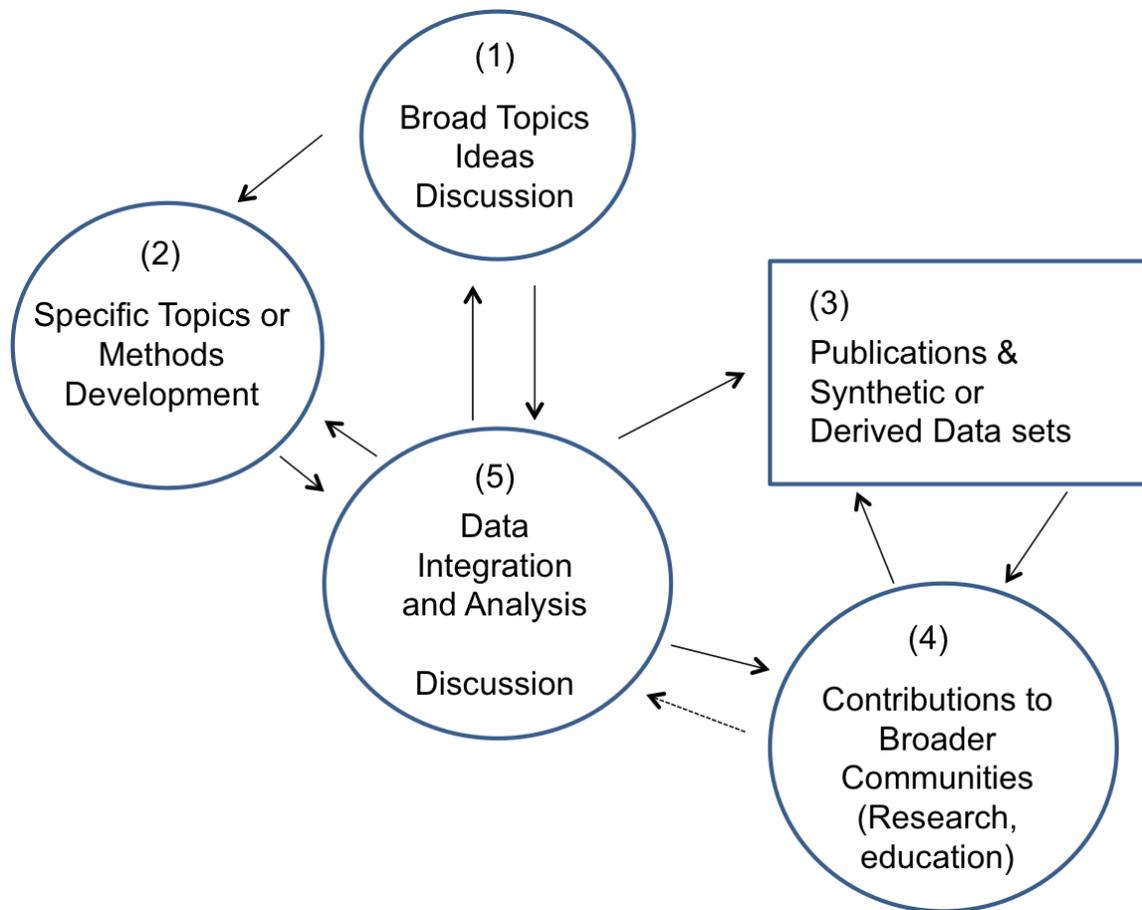


Figure 1: LTER synthesis activities advance ecosystem science by acting as incubators for new ideas (1) and forums for discussing emerging environmental trends (3,4,5). Synthesis activities also advance application of new methodologies in ecological science to address the 5 core areas (2). The ability for data integration will provide important information for the broader community to supplement information gained in publications (3), or provide avenues for new research, which in turn will feedback to development of new data integration approaches.