

## Report of the 1999 LTER Technology Committee

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Edited by John Vande Castle



The LTER Technology committee met at the San Diego Supercomputer Center on March 26 and 27, 1999 to review LTER technological developments and provide recommendations for the LTER Network on needs for current and new technologies. Recommendations for LTER Technology Development related to National Ecological Observatory Network (NEON), Information Technology (IT) issues, other potential funding opportunities.

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Summary:

The Committee discussed requirements for establishing a network of ecological observatories, as well as new issues surrounding information technology. The Committee also discussed potential funding opportunities, especially in regard to advanced computing, acquiring and processing new remote sensing data, and new methods for acquiring LTER site measurements.

It became apparent that cooperation with the LTER Committees for Information Management and Climate, as well as the LTER Coordinating Committees is necessary because of overlaps in goals and requirements within each of these committees. While the Technology Committee concluded that work toward recommendations for the LTER Network depends on this cooperation, results of preliminary discussion are listed below. The Committee plans to meet again in early 2000 to formulate a more complete list of recommendations for LTER technological development. The following summary lists recommendations for computer technology, remote sensing data and LTER site field and laboratory measurements:

**Computer Technology:** The Technology Committee recommended that the original definition of the LTER site Minimum Standard Installation should be viewed in light of the rapid pace of technological change. The "server" component should be considered within the context of current, 500mhz multiple processors, and online archival storage in the range of 1 terabyte to encourage online data storage including video, GIS and remote sensing imagery. Software components should include current database technologies for data search and retrieval. Geographic Information System and related components should include remote sensing tools for advance image processing related to high spatial (1m) and high spectral resolution (>200 waveband) data as well as advance visualization and modeling tools. Video conferencing, and general data communication technologies (whiteboard and presentation software) should be more widely used across the LTER Network for conferencing and remote meeting access. Network connections at field sites and home institutions should include uses where applicable, of wireless technology, T1 and very high performance Backbone Network Service (vBNS) Internet connections. LTER should also make better use of high performance computer installations those with developing collaborations with the San Diego Supercomputer center for large-scale data storage, modeling and visualization.

**Remote Sensing data:** The primary recommendation related to LTER remote sensing technology was to take advantage of the vast array of remote sensing technology related to the NASA/EOS "TERRA"-platform launch and other remote sensing data sources. With the successful launch of Landsat 7 on April 15 and its relatively inexpensive data, the LTER Network should coordinate efforts with NASA to fulfill recommendations of previous committees for Landsat data acquisition of all LTER sites on at least an annual basis.

**LTER Site and Field Measurements:** The committee recommended that the LTER Network should apply tools for the automation of site measurements wherever possible. The committee thought LTER should make more use of portable computer technology for field notes, real-time data communications and datalogging systems with automated data transmission packages using spread-spectrum wireless, cellular digital packet data (CDPD) data or other technologies for communication and transmission of data. Automated measurements should use of robotic packages for observations beyond conventional systems, including small scale tunneling systems, night observation video, and small scale aerial observation systems. The LTER Network should make better use of miniaturized technology such as micro-sensor systems - so called "laboratories on a chip" for both field and laboratory measurements. Field measurements could include automated camera systems and small-package GPS systems for animal observation and tracking. Standardized genetic mapping tools for species identification, with long-term sample preservations and storage, should be implemented across the LTER Network. For applications related to an ecological observatory network, science platform tower installations should be installed as an augmentation of the more conventional LTER meteorological site installations. Such installations could include use of automated observations systems including both video and audio technologies for recording site characteristics, monitor plot growth studies, and to record insect and animal species characteristics. Standard "WebCam" technologies should also be applied to LTER site observations and experiments.

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#### **LTER Technology Committee Presentations:**

- [Review of LTER Technology](#) ([PowerPoint version](#)) – **John Vande Castle**
- [Baltimore Ecosystem Study](#) ([PowerPoint version](#)) - Data management issues - **Samuel Walker**
- [National Ecological Observatory Network](#) ([PowerPoint version](#)) - **Bob Waide**

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## **I. LTER Communications Technology:**

### **Science Needs and Process**

We require better spatial and temporal resolution for measurements at our study sites. This requires better remote instrumentation, including automated data acquisition and collection methods (with embedded QA/QC). In order to control, transmit and receive (data transmission, instrument control, etc.) a complete communication network is required. In addition, a functional wireless communication system is needed. Large volumes of data will result so there is a need for mass storage systems. An indexing system across the LTER network (search and query tool) will be required for data access and exchange. Develop documentation and sharing of relevant information, data and communication methods within the LTER network and other users.

### **Technology Needed (MSI)**

The scientists on an application specific basis are addressing the science platform issue. However, the fundamental elements include both computer software and hardware, in addition to wireless communication systems. One specific need is a software

application that can support search and query actions (for data), within the LTER network. MSI need to be specified with mass storage devices capable of storing a minimum of 1TB initially. Dynamic wireless systems need to be able to support existing open communication standards and devices. LTER sites will need to be capable of supporting vBNS distribution and large-volume transmissions.

**Priorities**

Identifying and evaluating available wireless technologies is critical. The adoption of satellite technologies for general communication purposes is also a key priority. Initiating and maintaining communication with companies and agencies that provide these types of services or tools. Promoting access to existing and future data sets, and enabling the LTER sites to distribute and acquire these data. Identify personnel needs to support these initiatives.

**Applications of Interest**

Nano-technology, autonomous vehicles, biotic tracking and monitoring devices, mass storage evolution, digital field notebook, visualization and imaging techniques, RS technologies.

**Suggested MSI Components**

Mass storage devices (1 TB per site), required computer processing speed (450 mHZ), vBNS connectivity, on-site ODBC system capability (TBD), science platform towers, telemetry capabilities (TBD).

**II. Physical Measurement - Technology Applications**

**Science Needs:**

The overriding science need is to characterize, understand, and predict the biophysical environment, including understanding the complete physical matrix in which biota exist. These measurements encompass our capturing, to the best of our ability, environmental variation in time and space. At each site the system needs to monitor parameters that cross disciplines. One specific scientific goal is to assess long term environmental changes related to both natural cycles and anthropogenic changes.

**Technology Needs:**

The specific technology needs call for robust instrumentation that includes redundancy for key parameters. This equipment needs to perform in locations and conditions and at time intervals unsuitable for human participation. The instrumentation will require clean adequate power that can accommodate future expansion. Fundamental to the instrumentation will be the ability to transmit the data continuously from the remote locations using dependable wireless communication. This instrumentation should be housed on a platform that spans the vertical aquatic and terrestrial environments, ranging from the substrates in aquatic systems to above the canopy in terrestrial systems. Each study site should have a platform in a location with standardized characteristics and a platform located in the study area of interest.

In the event that catastrophic events cause significant down time, the site needs redundant instrumentation that can be deployed in a short time. Sites will need to develop a standardized data reduction protocol for remotely sensed, transmitted data, including QA, QC. In addition, we will need to develop sensors or protocols to measure parameters not easily or reliably measured now, e.g., Nitrogen trace gases.

Priorities range from technologies that can be implemented today, to developing technologies that do not yet exist. An initial step will be to transmit the data being collected at LTER sites today, using existing sensing technology with developing wireless technology. Standardize equipment across the network to the degree necessary or practical. All participating sites should meet the same minimum standard, i.e., level three recommendations of the LTER Climate Committee. As new equipment and procedures are developed, there should be a period of "phase-in" of new technology, in which the new technology and currently used methods are run concurrently for cross-calibration and standardization.

Science Needs	Technology Needs	Priorities
Characterize, understand and predict the biophysical environment	Robust instrumentation	Transmit the data using existing sensing technology with developing wireless technology
Understand the complete physical matrix in which biota exist	Key parameters need some form of redundancy	Standardize equipment across the network to the degree necessary or practical

Capturing to the best of our ability, environmental variation in time and space		Provide clean, adequate power to the instrumentation, including future expansion	All participating sites meet the same minimum standard, i.e., level three recommendations of the LTER Climate Committee
At one site, the monitoring system cuts across scientific disciplines		Transmit the data continuously using wireless communication	Developing new equipment and procedures
Assessment of long term environmental changes related to natural cycles in anthropogenic impacts		State-of-the-art sensors	During phase-in of new technology, there must be a time period in which the new technology and standardized methods run concurrence
To partition environmental change between its anthropogenic and natural sources		Instrument platforms, with one located within the system of interest and one within a location with standardized characteristics. Platforms must be able to integrate technologies from the biology group	
		Redundant instrumentation that can be deployed in a short time	
		Develop a standardized data reduction protocol for remotely sensed, transmitted data - QA, QC	
		Developing sensors or protocols to measure parameters not easily or reliably measured now, e.g., Nitrogen trace gases	

### III. Biotic Measurements

#### Science Needs:

The scientific needs for LTER Technology are based with the 5 core research areas. The specific needs is to quantify and describe the patterns in space and time of these five key areas. There are currently technological constraints that limit the efficient collection and communication of core research measurements. New technologies exist or are emerging which can be accessed to improve this situation.

#### ◆ Disturbance

- Identify and quantify patterns of change in land use and land cover.
- Current sensors have inadequate temporal and spatial resolution to monitor temporal and spatial change (e.g., gaps in forested systems)
- Separation of anthropogenic and natural disturbance
- Monitoring changes in community structure after disturbance
- Appearance of exotic species
- Can't detect immigration into system
- Infrequently observe actual disturbance event, only the results
- Need to measure both direct and ancillary effects
- Monitoring schemes need to be designed to track multiple kinds of disturbance (including unanticipated disturbances) and their interactions

#### ◆ NPP

- don't have ability to measure with sufficient frequency
- don't have standardized methodology
- don't have capability to measure major components of NPP, e.g, belowground productivity, herbivory, organic gas fluxes, root exudates (see Brown et al. submitted)
- scaling issues

#### ◆ Inorganic fluxes and pools

- Quantifying spatial and temporal variability
- Certain fluxes rarely measured (e.g., weathering, dry deposition)
- Scaling issues
- Measurements not taken at same place or time
- Incompatibility between measurements (e.g., point sample of rainfall vs. integrated measure of export)
- Some processes inadequately measured (e.g., anything that happens in the soil)
- Budgets depend on untested assumptions (e.g., impenetrability of bedrock)
- Linkages back to populations and communities rarely measured
- Poor understanding of relationship between decomposers and decomposition, especially partition between physical and biotic factors

#### ◆ Organic material

- Characterization of spatial and temporal variability
- Poor understanding of nature (quality) of organic material
- Poor understanding of relationship between decomposers and decomposition, especially partition between physical and biotic factors
- Certain fluxes rarely measured (e.g., DOC, DON)
- Scaling issues; little attention paid to very large or very small scales
- Measurements not taken at same place or time
- Incompatibility between measurements (e.g., point sample of soil carbon vs. integrated measure of export)
- Some processes inadequately measured (e.g., anything that happens in the soil)
- Linkages back to populations and communities rarely measured

#### ◆ Populations and trophic structure

- Taxonomic capacity to characterize biodiversity uniformly across trophic levels
- Quantitative estimates of population size difficult for some organisms
- Lack of standardization of methods for sampling as well as temporal and spatial frequency of measures
- Feedback to ecosystem processes poorly understood
- Discordance between rates of changes and periods of population cycles for different organisms
- Untested assumptions abound (e.g., emigration and immigration)
- Difficulty of characterizing interactions among trophic levels

#### ◆ Measurements - Technology

- Stable isotopes
- Audio and visual technology linked to smart technology identification
- Remote sensing at all scales, including sonar, radar, lidar
- Remote, frequent data acquisition
- Any technology that helps us understand belowground
- Lacking technology to measure aerobiota
- Micro-gps systems
- Identification of species from protein samples, including genetic identification and spatial mapping of alleles
- Automating capture-recapture
- Remote measurements of stress physiology
- Tracking human impacts on ecosystems via differential use of space (using gps transmitters)
- Robotics, both automated samples and rovers

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#### LTERR Technology Ideas and Suggestions:

Investigate and implement capabilities for more non field data acquisition and transfer of data. Sites could use more methods to collect and record data in more efficient ways than on paper and pencil. Examples would include portable computer, voice recognition systems, and include digital audio, digital video, and related technologies.

LTERR needs to reassess remote sensing issues. With the launch of new instruments, it is a critical time for LTERR to define how it can use these technologies. LTERR should be able to define ways that the new technology can be used in ecological studies. Digital imaging systems are now more available, and could be used with small aircraft systems. Sites could use portable imaging systems to augment more standard remote sensing technologies for measurements to include phenological changes or other types of changes at various scales. This type of technology is, for example, used by Greg Asner in conjunction with a LIDAR system for canopy studies. There is a NASA office that spends time to investigate what are the "best" instruments for various applications, such as recommended spectrometers, GPS systems etc.- Greg Asner will provide contact information for

this.

ILTER should make more use of tools for recording site and plot level processes. The instruments need to be both simple and robust so measurements can be made by field technicians and students - Li-Cor measurements of LAI as an example.

Connectivity for field instrumentation is needed for instruments that move around or are too far for wire transmission. Wireless communication or direct and continuous data links for things like monitoring flow rates, tidal fluctuations etc. Technologies such as cellular CDPD data transmissions and other technologies such as spread spectrum radio technology, or other future technologies should also be investigated.

ILTER should develop new information technology related to controlling individual instruments and sensors - direct Internet connections to control sensors and instruments. This could include instrument development initiatives that have been funded by NSF, NASA, National Labs and the private sector

Electrical power needs at field installations should be evaluated. Power modules for various instruments need to be considered. Technologies like fuel cells, similar to what is planned for automobiles should be evaluated.

Instrumentation to cover events where people are unable to be present to monitor certain events, such as extreme weather or other hazardous events. This means being able to maintain connectivity and power to keep instrumentation and observations active. Many of these technologies already exist in the private sector and military. Technologies already developed at national labs and especially NOAA should be investigated. An example is the NOAA buoy systems.

Technology needs of social science activities, and ways of collecting and transmitting data related to augmented LTER, urban and agricultural initiatives.

Measurement and monitoring of biotic processes should be made, in a manner similar to the past focus on automation of physical measurements at LTER sites. Measurement of biological processes will be required for future observatory initiatives.

Canopy structure measurements techniques need to be addresses. This includes standard canopy access techniques such as towers, but other techniques such as laser assessments for measurement of tree gaps, or other profile measurements systems. Similar attention should be made to spatial data acquisition systems for horizontal transects and vertical profiling systems in aquatic systems.

Besides general monitoring, technologies are needed to more easily implement experimental manipulations, for example to change physical influences, such as rainfall enhancement, wind enhancement etc.

Robotic instrumentation needs to be evaluated.

A list of what variables LTER needs to measure should be set up. This should include a prioritized list of variables, and those with high priority should be a focus. Instrumentation should be evaluated and installed to cover these variables. The instrumentation should be hardened to provide a continuous flow of data regardless of what type of expected disturbances might occur - i.e. floods, hurricanes, earthquakes etc.

Rapid deployment of instrumentation should also be available for deployment during from remote locations during and throughout extreme events. An example is the large flow of materials following storm events.

Attention to scale issues need to be addresses - both grain and extent of observations. This will depend on the science issues being addresses.

ILTER needs to evaluate the specific investigation packages have been developed by the commercial sector. These specialized "turnkey" instrument packages acquire specific and standardized data (temperature, pressure, shock measurements etc) and produced in mass quantities, could be widely implemented across LTER sites and the Network as a whole. Related to this would be the development of a complete package including a range of devices to measure key variables including biotic measurements, and include necessary communications technology to transmit and process and store the information.

Miniaturization technologies such as nanotechnology and gps instrumentation should be considered. An example is the use of miniaturized GPS technology for bird migration tracking and other animal, or perhaps physical movements. GPS instrumentation could be expanded to much more of LTER science. The technology has advanced faster than its current incorporation into LTER research.

Genetic information and location mapping of this type of information needs to be implemented within the LTER network.

Remote sensing data should be geometrically and radiometrically corrected. A lab or procedure to have this done would be useful.

Commercial labs to do identifications such as pollen, plankton and fish could be identified and used for some of the more tedious monitoring.

The Internet could be used to better advantage for exchanging imagery of samples and organisms. Better organization of the data such as inclusion of xml to include of metadata within the data stream, for example imbedded within imagery information should also be evaluated and implemented.

Video conferencing should be expanded to the LTER sites, especially related to white board and simple data transmission. Little use of off the shelf technology such as "NetMeeting" web technology has been made, and could be implemented at little costs. Related to this, WebCams should be implemented on a more wide-scale basis. This would contribute not only to scientific measurements, but to dissemination of information . This could be used for scientific studies such as phenology changes, plot growth studies etc. Video data from WebCam technology would be useful for recorder experimental manipulations and extreme events, and could be use as a way to distribute this type of information on a wide-scale, Internet based method.

Nutrient flux measurements, especially linked to rhizotron measurements should be evaluated, to include technologies needed for these types of observations. Remote sensing technologies should be included investigated of technologies related to belowground processes.

The LTER MSI should be reassessed including storage issues for data generated by new technologies need to be addressed. This includes how to store LTER site and Network wide imagery as well as data from automated sampling devices and model output.

Personnel issues needed for implementation of new technologies also need to be addressed. Implementation of new technologies requires people who are technically competent in the various areas to install and maintain software and equipment.

For much of the activity, an element of standardization will need to be employed. More standardization of individual site data will be important in the implementation of observatory systems to include data acquisition procedures, physical and biotic measurements.

The scientific questions need to be discussed and defined - and what technologies are then needed. Input on - Specific scientific questions that need to be address in ecological observatory efforts will be addressed at the spring LTER CC meeting in Puerto Rico.

A better information flow of what new technologies that really work need to be implemented. Related to this, a survey of both current technology as well as technological needs LTER sites should be made. The LTER Technology Committee should be able to act as a distributed entity to collect information on new technologies and distribute and implement useful technology within the LTER Network. A listserver for TECHCOM should be set up for discussion of new technologies within LTER, and in general, The LTER Technology Committee should be able to act as a distributed entity to collect information on new technologies and distribute and implement useful technology within the LTER Network.

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#### LTER 1999 Technology Committee Meeting Agenda - Friday March 26 :

8:30am · Background and local logistics: Tony Fountain

· Overview and background - past committee recommendations - John Vande Castle · Presentations by attendees:

- Regional Modeling - Stuart Gage
- Near future and future remote sensing applications, tools, - Greg Asner
- Data management issues, online data, metadata - Samuel Walker
- Charge to the Technology Committee: Bob Waide
- Discussion of current capabilities
- Discussion of what we aren't doing, and what tools we don't have but need

10:30am · Tour of SDSC Facilities - Tony Fountain

11:30am · Break for Lunch

1:00pm · Group Brainstorm Session

3:00pm · Break

3:30pm · Formation of Discussion Groups and breakout sessions

5:00pm · End of Session

#### LTER 1999 Technology Committee Meeting Agenda - Saturday, March 27

8:30am · Discussion Group Sessions

**10:30am · Initial Reports from Discussion Groups**

**11:30am · Lunch Break**

**1:30pm · Final Review and Discussion of Recommendations**

**3:00pm · Break**

**3:30pm · Online Report Preparation**

**5:00pm · End Of Meeting**

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