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Enclosed is a draft version of our report on technology development in the LTER network. In it we have tried to summarize the current status of various technologies, based on numerous reports and to present the results of responses to our questionnaire on GIS and remote sensing. We have also made some conservative recommendations for continued funding in order to complete the MSI and to accomplish various goals established by different working groups.

Your comments and suggestions are quite welcome. We are grateful for all of your assistance in assembling the report.

TECHNOLOGY DEVELOPMENT IN THE LTER NETWORK

Current Status of GIS, Remote Sensing, Internet Connectivity, Archival Storage and Global Positioning Systems

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SUMMARY

Since its formation in 1979 the LTER has expanded to form a network of 18 separate sites. During the course of this development a number of committees within LTER have recommended that NSF support the acquisition of common technological capabilities at the sites in order to enhance integrated studies and to improve information exchange. Major recommendations have covered the areas of GIS, remote sensing, connectivity, data storage and global positioning systems. NSF has responded to the recommendations by providing supplemental funding for technical acquisition. The current report assesses the progress made towards technology development in these areas across the Network. The report concludes that dramatic improvements have been made at all sites during the past two years that have had a major impact on individual site research and the ability of LTER to operate as an integrated network. Major accomplishments include competent GIS systems at every site, satellite data and high-level aerial photography for every site, GPS units that can be shared across the Network, and training for personnel in the use of these technologies. The report closes with the recommendation that the LTER Network seek to complete the technology development proposed by the original working groups and to study additional areas of technology development for future consideration.

INTRODUCTION

In September 1990 workshops on GIS, remote sensing, and global positioning systems were held at the All Scientists Meeting of LTER in Estes Park, Colorado. As part of the GIS workshop D. R. Foster and E. Boose polled all sites on GIS and remote sensing capabilities in order to assess the state of the Network, and to provide accountability to NSF on the effectiveness of the supplemental funding program in providing technological development and in promoting research, communication, and management activities. The present document is an outcome of that workshop, with a broadened scope to include Internet connectivity, archival storage and global positioning systems. Acknowledgement is given to James Brunt, William Michener, Rudolf Nottrott and John Vande Castle for their cooperation and assistance in compiling this report.

HISTORY OF THE MSI AND TECHNOLOGY SUPPLEMENTS

As background to the current analysis it is useful to review the development of the MSI and the funding initiatives for technology acquisition within the LTER. The following discussion highlights important stages in the emergence of a long-range plan for technological planning in the LTER network and reviews major workshop activities and funding opportunities.

The first formal planning for technological improvements in LTER is summarized in the report of the NSF advisory committee on scientific and technological planning for LTER projects, chaired by H. H. Shugart. On the basis of meetings with representatives of all LTER sites and with technical experts this committee made the following recommendations (Winter 1988) for priority in funding by NSF:

(1) Acquisition of Geographic Information System capability with some uniformity across the LTER network.
(2) Development of a network remote-sensing analysis capability.
(3) Augmentation of wide-area and local-area computer networks in the LTER system.

More broadly the Shugart Committee noted that the LTER Network requires a minimum level of common technological capability and an ability to communicate rapidly in order to function as a coordinated group. The report finished by recommending that GIS represents "the area offering the single most important technology advance for ecosystems studies in the LTER."

At the LTER Coordinating Committee meeting at Kellogg Biological Station in November 1988 representatives from all of the sites recommended that NSF enhance the development of common technologies in the Network through the funding of minimum standard installations (MSI) supported by supplemental funding. An LTER Worksheet was drawn up describing the MSI as follows:

(1) GIS system--small multi-user computer with high resolution color screen, digitizer, plotter, ArcInfo software, half-time technical person.
(2) LAN and WAN--local area network connecting at least some local

computers, access to a wide area network such as NSFNET through a host computer.

(3) High-capacity data storage system--optical disk drive (either WORM or erasable).

Two LTER working groups were established at the Kellogg meeting to explore technological development further: a GIS group chaired by D. R. Foster and a general technology group led by J. Gosz.

The GIS working group report built on recommendations at the Kellogg meeting that supplemental funding be directed towards enhancement of GIS and LAN/WAN. R. Robbins, NSF representative on the GIS working group, distributed a questionnaire across the LTER that concluded that (1) capabilities and facility support in these areas across the Network were highly uneven and generally poor, and (2) the configurations of software and hardware at sites supporting these activities were diverse. The GIS working group endorsed the MSI specification, while recommending that specific hardware and software choices were less important than compatible data formats and that all sites acquire both vector and raster GIS (compatible with ArcInfo and Erdas). It was felt that the MSI represented a highly competent system that would provide a network standard and would enhance research, management and communication activities within the LTER.

The Technology Working Group reviewed technologies not represented by the MSI. The group's report focussed on four types of research that would drive the acquisition of new technology and that were thought to be important in terms of their relevance to LTER goals, urgency in implementation, expertise available and cost. The four research areas identified include (in order of importance): (1) acquisition of satellite imagery for all sites, (2) biospheric/atmospheric interactions and measurements, (3) process modelling and spatial analyses, and (4) comparative experimental technologies. A series of additional important technologies were also listed.

On the basis of the strong concensus reached at the Kellogg meeting, the content of the two working group reports and a commitment within NSF to improve technology capabilities within LTER to an acceptable standard, two competitions for supplemental funding were held (February of 1989 and 1990) with an emphasis on technology acquisition. The majority of proposals sought to develop site competency (e.g. MSI) or additional strength in the areas of GIS and connectivity. Some remote sensing capabilities and other research support were also requested. The results of these two competitions, in terms of the implementation of the acquired equipment, are the focus of much of this report. Funding for technologies identified in the Gosz report has been largely restricted to Network-wide acquisition of remote sensing imagery, which is also addressed below.

During 1989 a series of workshops were funded by NSF either through the LTER Network Office or through direct grants to introduce principal investigators at the LTER sites to some of the major technologies. The workshops included (1) Wide Area Networking (Urbana, Illinois; April 1989), (2) GIS Training (Fort Collins, Colorado; September 1989), and (3) Remote Sensing (Durham, New Hampshire; November 1989). An additional series of mini-workshops were held at the LTER All Scientist Meeting at Estes Park, Colorado in September 1990.

As a major start towards connecting all LTER researchers via electronic networks, a wide-area networking (WAN) workshop with participants from all LTER sites was held in April 1989, at the University of Illinois. LTER representatives demonstrated the use of networks and various speakers introduced Internet resources, the evolution of NSFnet and the Internet, and network security. Also discussed were links between LTER sites, links to supercomputers, links to Internet resources relating to remote-sensing, centralized image processing and geo-referencing.

At the GIS Workshop organized by I. Burke, the major efforts were directed towards introduction to ecological applications of GIS, training in MSI GIS software and capabilities, and providing opportunities for inter-site exchange and interaction. The workshop was broken up into a 2-day introduction to GIS, a 4.5-day training session in ArcInfo and a 2-day training session in Erdas. Two participants from each site attended the workshop.

The remote sensing workshop organized by J. Aber was held at the Complex Systems Research Center at the University of New Hampshire and was strongly complementary to the GIS/ERDAS training session. Participants from most of the LTER sites as well as numerous remote sensing laboratories in the U.S. provided reviews of the major types of remote sensing data, satellite systems and software development and discussed specific case studies.

Leading up to and including most of the activities at the All Scientist Meeting, effort has been aimed at long-term planning of technology development, acquisition of systems and training of LTER personnel in the specific technologies. With the exception of a report issued by the Connectivity Committee in February 1990 there has been no attempt to summarize the extensive progress that has been made in developing technological capabilities and acquisition of the MSI across the Network. The following section provides this review including the results of the Connectivity report.

CURRENT STATUS OF TECHNOLOGY AND ACTIVITY IN LTER

GIS

Survey. In preparation for the GIS Working Group workshop at the All Scientists Meeting in September 1990, D. R. Foster and E. Boose (HFR) conducted a survey of GIS and remote sensing capabilties across the LTER network (18 sites, including NET). The purpose of the survey was to identify the systems currently in use at each site: the computer platforms, the GIS or remote sensing software used on each platform, and the primary uses of each configuration. The survey did not try to describe the number of systems, the funding and ownership of each system, or the personnel available at each site. Detailed results of the survey are given in an Appendix to this report.

A comparison of this survey with the survey of R. Robbins (NSF) conducted two years earlier shows a dramatic increase in GIS and remote sensing capability across the network. In the December 1988 survey only about half of the sites had a working GIS. In the current survey all sites have GIS capability. Most sites show an impressive array of vector and rastor GIS on a variety of computer platforms. More than half of the sites have remote sensing capability with Erdas.

Some summary statistics from the survey are given below. It is interesting to note that most sites are using a combination of Unix workstations and PCs for GIS and remote sensing. Apple Macintoshes were mentioned at only two sites and in combination with workstations and PCs. The only vector software cited was ArcInfo, while a wide range of raster GIS software was cited. Most sites that have Erdas indicated that they use it both for image processing and as a raster GIS.

TABLE 1. SUMMARY OF COMPUTER PLATFORMS AND SOFTWARE AT LTER SITES

COMPUTERS	# sites
Workstations + PCs	10
Workstations only	4
PCs only	4

SOFTWARE		# sites	# planned
vector GIS	ArcInfo	16	
raster GIS	MAP (various forms)	9	
	Grass	4	2
	Eppl7	4	
	Idrisi	2	1
	Moss	1	
	Panacea	1	
remote sensing	Erdas	11	2
	Las	1	
misc.	In-house	5	

Research. GIS provides an excellent tool for describing spatial variability and patterning of ecological attributes and processes and for examining long-term temporal variability in these factors. Interesting research applications of GIS are being developed at many sites, as indicated in responses to the survey and in discussions at the All Scientists Meeting. Highlights of current GIS-related research at selected sites are given below:

AND - Modeling movement of sediment and coarse woody debris through streams. Analysis of landscape patterns of disturbance. Modeling of management scenarios for conifer forests in PNW.

CPR - Application of the Century model to Central Plains GIS data, to make long term regional predictions about the potential effects of climate change.

HBR - Patterns of soil temperature and moisture and their responses to regional climatic change senarios. Vegetation-environment interactions and their influence on patterns of soil nutrient retention and plant nutrient stress. Relationships between variability in emissions of C, N, and S gases and the topographic, soil and vegetation parameters that regulate substrate availability and soil drainage.

HFR - Analyzing landscape-level patterns of forest damage from hurricane Hugo in Luquillo Experimental Forest in terms of local topography and storm dynamics (damage estimated from aerial photographs). Studying spatial correlation between land-use practices and vegetation in central New England since settlement times.

JRN - Modeling wind erosion and overland flow.

KBS - Modeling spatial dynamics of insect movement in local and regional landscapes, including dynamics of beneficial insects at KBS, and population prediction and risk assessment of the gypsy moth across Michigan.

LUQ - Studying correlation of topographic aspect with forest damage from hurricane Hugo (damage estimated from satellite images). Modeling habitat and migration of stream shrimp.

NWT - Studying effects of topography and snow distribution on vegetation.

SEV - Studying correlation of lightening strikes and rainfall, and correlation of topography and location of trapped animals.

Site management. Several sites are now using GIS as a site management tool. A formidable problem for every LTER is the problem of managing the land base for potentially conficting uses: e.g., research, education, nature reserves, resource management. Site managers must be able to rapidly locate and allocate appropriate sites for new activities while at the same time assuring the viability of existing projects. Over time a large number of diverse activities makes this a complex cartographic chore. GIS provides a tool that can rapidly assist in maintaining records and making decisions, once the base data for the site has been digitized. It is likely that nearly all sites will be using GIS for site management in the next few years.

Data management. GIS provides an efficient means for recording, storing, and displaying cartographic information. In this sense, GIS can be regarded as a data management tool: it provides an alternative, for example, to hand drawn paper maps for recording and displaying cartographic data. Many sites are finding that the extra work involved in digitizing and maintaining GIS files is justified by the ease of manipulation and display that GIS affords.

At the same time, the use of a GIS adds considerably to the data management tasks at each LTER site. GIS and remote sensing data pose several problems not found with ordinary non-spatial tabular data: e.g., the overlay files tend to be quite large, it is easy to make numerous derivative overlays without clearly documenting the derivation, errors can be very difficult to locate, overlays require considerable documentation and in most GIS systems the documentation does not reside in the overlay file.

Initial discussion of these and related issues concerning the data management aspect of GIS has been undertaken by the LTER Data Managers. At last summer's meeting the Data Managers proposed a GIS/remote sensing/data management symposium that would consider standards for scale, classification, and documentation. Development of network-wide standards, where feasible, could facilitate intersite research in the future.

Recommendations for information exchange. At the All Scientists Meeting there was general agreement that no single available GIS system meets all the needs of LTER scientists. Nearly all commercial GIS systems have been developed for cartographic and not scientific applications, and so typically lack functions such as spatial statistics that are essential for scientific research. Also, no current system combines all the advantages of vector and raster GIS. As a result, most sites currently use more than one GIS system, and many sites (at least five) have developed their own in-house software to implement special functions or to provide an interface to spatial models.

It became clear at the All Scientists Meeting that the LTER Network could benefit from dissemination of information about new software and new techniques developed at individual sites. In many cases such sharing of information could reduce duplicated effort. The LTER electronic bulletin board was suggested as a possible forum for this interchange.

REMOTE SENSING

Survey. More than half of the LTER sites indicated that they have software for remote sensing data analysis. Of these, eleven sites are currently using Erdas on workstations and/or PCs, while two more sites are planning to acquire Erdas, and one site is using Las. Two sites mentioned that they also have access to more extensive facilities at a university remote sensing laboratory--the same is probably true for some other sites as well.

There is a strong interest across the LTER Network in improving remote sensing capabilities, as a means of scaling up ecosystem analysis and as a complement to the growing expertise in GIS. Representatives from all sites received training in Erdas at the GIS training workshop in Fort Collins, and most sites were represented at the remote sensing workshop at the University of New Hampshire.

Network data acquisition. Important obstacles to research based on remote sensing are the expense and complexity of acquiring the data, and the restrictions on data sharing imposed by data copyrights. However, the scientific advantages of remote sensing, especially for regional and intersite studies and for the assessment of global change, are great, and the acquisition of satellite imagery for all LTER sites was the number one recommendation of the Gosz Committee. This recommendation received unanimous support at the remote sensing workshop, where details of possible acquisitions were discussed.

In September 1990, NSF funded a proposal by the LTER Network Office to acquire the following data for each LTER site:

(1) one Landsat-5 Thematic Mapper full scene, 30 m. resolution, 7 spectral bands, less than 30% cloud cover.
(2) one SPOT-HRV panchromatic scene, 10 m. resolution, less than 10 % cloud cover, clear coverage for site.
(3) regional AVHRR data from NOAA and USGS sources, 1 km. resolution.
(4) current HAP (high-altitude photography) from USGS in film format.

(5) retroactive search for all data available from the SPOT and Landsat Archives.

The data will be purchased and archived by the LTER Network Office, under the direction of J. Vande Castle, and distributed to sites on computer tape, optical disk, or by network link (depending on the individual site's capabilities). The data files are quite large: each Landsat scene is about 300 megabytes, each SPOT scene is about 50 megabytes, and each AVHRR scene is about 60 megabytes. A shared license agreement has been negotiated with the private companies involved, so that any or all site data may be used by any site.

This collective database will be the basis for a wide array of collaborative research across the LTER Network. The digital satellite data and aerial photography will function as an historical record and common means of comparison for each LTER site. And the acquisition will act as a "test case" for future acquisitions from EOS era space platforms.

INTERNET CONNECTIVITY

The LTER Connectivity Committee chaired by J. Brunt was established in July 1989 and charged with assessing the current connectivity of LTER sites to the Internet and with making specific recommendations (with cost estimates) to the LTER Coordinating Committee and to NSF. During the fall of 1989 the Committee formally visited five LTER sites and informally visited four others, and delivered its report (Internet Connectivity in LTER - Assessments and Recommendations) in February 1990. The Committee's findings and recommendations are summarized below.

Computer networking technology can now virtually eliminate the physical and temporal barriers to scientific collaboration. The National Science Foundation Network (NSFNet) and associated mid-level networks, commonly referred to as the Internet, provide a common and stable thread with which LTER investigators are being joined. This network of networks is predicated on communications software standards, the Internet protocol suite, that enable a wide array of heterogeneous computers to exchange data and information. Increased levels of connectivity are responsible for new intersite activities, such as a distributed climate database and online dataset catalog, as well as greatly increased use of electronic mail through the LTERNET mail forwarding system.

Despite the advantages of Internet connectivity, and despite the fact that nearly 90% of the universities that administer LTER grants have connections to the Internet, the Committee found that the majority of LTER computers, all of the field laboratories, and many PIs remain isolated from Internet capabilities. In many cases there is a missing link between an LTER computer and the Internet access point on campus; in some cases (e.g., field sites) the nearest Internet access point must be reached via telephone or radio. Detailed information for each LTER site is presented in the Connectivity Report.

The Committee recommended that the LTER Network pursue complete Internet connectivity through the addition of equipment, personnel, and education directed at networking. Three steps were recommended for each site:

(1) Develop a basic LAN infrastructure with connections to the Internet at the main location of each LTER site to provide at least minimal access to Internet services.
(2) Upgrade LAN facilities at main locations to provide complete Internet connectivity and provide E-mail service to remote sites.
(3) Establish full Internet connectivity and LAN infrastructure at large field sites.

Other recommendations included funding for technical personnel in networking, acquisition of at least one multiuser UNIX (or variant) computer at each site to provide E-mail and network services, workshops involving advanced uses of computer networks in ecological sciences and technical instruction (e.g., a UNIX system admininstration workshop), and production of a networking manual to assist sites in developing their networks.

ARCHIVAL STORAGE

The need for a high capacity data storage system to accompany a GIS was recognized in the original MSI specification, which included an optical disk drive (either WORM or erasable). In the past two years that need has increased with the development of large online databases and especially with the LTER Network acquisition of remote sensing data for each site (a single scene is typically 50-300 megabytes). Though data storage systems were not covered in the current survey, it is our impression that few sites have used supplemental funds to acquire these systems, in part because other technologies (such as GIS) have overshadowed data storage, and in part because industry standards have not yet developed for optical disks. A recent survey of protocols for archival of LTER core data sets (Barbara Benson, LTER Databits, Fall 1990) shows that all ten sites responding to the survey are using magnetic and not optical media for data storage, though several sites have plans to acquire optical technology.

Despite the current lack of industry standards, optical disk technology still appears to be one of the most promising solutions to the problem of affordable, reliable, high capacity data storage. With the increased use of large databases, GIS, and remote sensing, many LTER sites will soon be forced to purchase some kind of high capacity storage system--in most cases, an optical disk system.

GLOBAL POSITIONING SYSTEMS

The Global Positioning System (GPS) was developed by the U.S. Department of Defense to provide accurate geopositional data for any point on the earth's surface. The GPS utilizes computers and a constellation of 21 NAVSTAR satellites orbiting at an altitude of 10,900 nautical miles to triangulate positions on earth. Though not part of the original MSI specification, GPS technology has great potential for complementing the MSI: e.g., it can be used for surveying and for georeferencing GIS and remote sensing data.

In the spring of 1990, NSF funded a proposal (organized by W. Michener at NIN) to purchase GPS units for use across the LTER Network. The following equipment has been purchased:

(1) Four pairs of Trimble Navigation Pathfinder GPS units. When used as a pair, with one unit at a known location, these units provide 2-5 m. accuracy, good enough for USGS 1:24000 map accuracy standards. These units are rugged, portable, and relatively maintenance-free. Pathfinder software has post-processing, display, plotting, and GIS interface capability. Training for these units was conducted at the All Scientists Meeting in September 1990.

(2) One Trimble Navigation 4000 SST unit. This survey grade unit provides spatial resolution down to centimeters. It is less portable and much more difficult to use than the Pathfinder units. The unit is currently being tested.

Current plans call for four sites to serve as regional centers for the Pathfinder units (AND, CDR, SEV, NIN). Regional centers will provide distribution and support for the LTER sites in their region. The high precision unit will be based at NIN, and will probably require a traveling team of experts for its use.

RECOMMENDATIONS FOR FUTURE DEVELOPMENTS

NSF funding over the last two years has produced dramatic technological improvements across the LTER Network. Major accomplishments include competent GIS systems at every site, satellite data and aerial photography for every site, GPS units that can be shared across the Network, and trainng of representatives from all sites in the use of these technologies.

The original recommendations of the Shugart Committee, developed and augmented over time as described in this report, remain sound goals for technological funding of the LTER Network by NSF. Areas that could be improved by further technological funding are described below:

Remote sensing. The sites that currently lack remote sensing capability (about 6 sites) should have the opportunity to acquire it. Erdas or similar systems would permit these sites to take advantage of remote sensing data acquired by the Network.

Internet connectivity. The goal of complete Internet connectivity should be pursued. As the Connectivity Report suggests, this will require several years of ongoing effort and funding.

Archival storage. High capacity data storage systems--in most cases optical disk systems--are rapidly becoming essential at all sites to handle the volume of data associated with large databases, GIS, and remote sensing.

Global positioning systems. Two more pairs of Pathfinder units, to be located in the central and northeastern U.S., would alleviate logistical problems and improve accessibility to these units.

Data base software. The need to acquire new database software, especially software that supports SQL (structured query language), was discussed at last summer's LTER Data Managers Meeting. The Network would like to take advantage of ongoing improvements in software design, and some sites will need to acquire SQL software in order to participate in Network projects such as the distributed climate database.

The first recommendation of the Gosz Committee, network acquisition of remote sensing data, is now being carried out. The third recommendation, process modeling and spatial analysis, will be greatly aided by the MSI improvements, both implemented and proposed. The remaining recommendations describe a variety of other technologies, such as trace gas flux measurements and whole ecosystem manipulations, that should be studied by the LTER Network for future consideration.

APPENDIX

LTER GIS / REMOTE SENSING SURVEY September 1990 (* = planned)

Site	Computer	Software	Primary uses
AND	Sun 3/280	ArcInfo 5.0.1	landscape modeling, site inventory
	Sun 3/60	ArcInfo 5.0.1	landscape modeling, site inventory
	Sun 4/110	ArcInfo 5.0.1	landscape modeling, site inventory
	Sun 3/60	Erdas 7.3	image processing, interface between image data & ArcInfo
	Sun 3/60	Grass	supplemental raster GIS
	DG MV 15000	Moss	supplemental raster GIS, access to National Forest data
	Sun 4/110	In-house	ArcInfo interfacing menus, Sun Xwindows interface for Grass, programs to supplement GIS
	*Sun sparc	*ArcInfo	landscape modeling, site inventory
ARC	Sun sparc	ArcInfo	vector GIS
BNZ	Sun 4/390	ArcInfo	vector GIS
CDR	Sun 386i	ArcInfo 4.0.2	vector GIS [St. Paul]
	PC 286	Eppl7 2.0	raster GIS [St. Paul]
	Sun 386i	*Grass	raster GIS [St. Paul]
	*Sun sparc-1	*ArcInfo 5.1	vector GIS [St. Paul]
	PC	ArcInfo	vector GIS [Minneapolis]
	=> access to additional facilities at Univ. Remote Sensing Lab		
	=> network access [from Minn.] to Vax running ArcInfo [in Duluth]		
CPR	Dec work st.	ArcInfo	vector GIS
	Sun 386i	ArcInfo	vector GIS
	Sun 386i	Grass	raster GIS
	PC	ArcInfo	vector GIS
	PC 286	Erdas	image processing & raster GIS
CWT	Sun sparc-1	ArcInfo	vector GIS
	*Sun 4/110	*ArcInfo	vector GIS
	*Sun 4/110	*Erdas	image processing, raster GIS
HBR	Tektronix 43xx	ArcInfo 4.0	vector GIS [Cornell]
	PC 286	Erdas 7.4	image processing [Cornell]
	PC 286	OSU map	raster GIS [Cornell]
	*PC 386	*ArcInfo	vector GIS [Hubbard Brook]
HFR	PC 386	Map	raster GIS analysis & modeling
	PC 286	Panacea	raster digitizing & editing
	PC 386	In-house	additional GIS functions, spatial statistics, spatial models, graphics, file conversion
	PC 386	*Mapbox	raster GIS
	PC 386	*Idrisi	raster GIS
	PC 386	*Erdas	image processing

Site	Computer	Software	Primary uses	
JRN	Sun 4/110	ArcInfo 5	vector GIS	[Las Cruces]
	Sun 4/110	Erdas 7.3	image processing	[Las Cruces]
	PC 386	Geoeas	mapping	[Las Cruces]
	VVax 6000	ArcInfo	vector GIS	[San Diego]
	VVax 11/750	ArcInfo	vector GIS	[San Diego]
	Sun sparc	ArcInfo	vector GIS	[San Diego]
	Sun sparc	Erdas	image processing	[San Diego]
	PC 386	ArcInfo	vector GIS	[San Diego]
	PC 386	Erdas	image processing	[San Diego]
	Mac II	Map II	raster GIS	[San Diego]
	Mac II	Idrisi	raster GIS	[San Diego]
	*IBM power st.	*Spans	raster GIS	[San Diego]
KBS	Vax 3100	ArcInfo 5.0	vector GIS	
	PC 386	ArcInfo	vector GIS	
	PC 386	Erdas	image analysis & raster GIS, modeling	
	PC 386	Live-Link	integration of vector & raster GIS	
	PC 386	In-house	data conversion to ArcInfo format, Erdas data entry & conversion, integration with video images	
	PC 386	Cmap	digitizing	
KNZ	Sun 4/110	ArcInfo 5.1	vector GIS	
	PC 386	ArcInfo	vector GIS	
	PC 386	Erdas 7.4	image processing & raster GIS	
	PC 386	Live-Link	integration of vector & raster GIS	
	PC 386	Map	education, small research projects	
	PC 286	Pmap	education	
	PC 286	OSU Map	education	
	PC 286	Idrisi	education	
LUQ	PC 386	Erdas 7.4	image processing & raster GIS	
NET	Sun sparc-1	ArcInfo	vector GIS	
	Sun sparc-1	Erdas 7.4	image processing & raster GIS	
	Sun sparc-1	Live-link	integration of vector & raster GIS	
	Sun sparc-1	Grass 3.1	raster GIS	
	PC 386	Map	raster GIS	
	PC 386	Eppl7 2	raster GIS	
NIN	Sun sparc-1	ArcInfo	vector GIS	
	Sun 330	Erdas	image processing & raster GIS	
	Sun 330	In-house	programs to supplement Erdas	
	PC 386	ArcInfo	digitizing & editing, GIS documentation	
	PC 386	Erdas	image processing & raster GIS	
	PC	OSU Map	raster GIS	
	PC	Eppl7	raster GIS	

Site	Computer	Software	Primary uses
NTL	PC 386	ArcInfo 3.3	digitizing, vector GIS, modeling
	PC 386	Erdas 7.4	digitizing, image processing, raster GIS, modeling
	PC 386	Live-Link	integration of vector & raster GIS
	PC 386	Eppl7 2	raster GIS
	PC 386	In-house/Erdas	raster GIS analysis & modeling
	PC 386	In-house	image processing & analysis, modeling, expert systems
	PC 286	Map	raster GIS & modeling
	=> access to additional facilities at Environ. Remote Sensing Center		
NWT	Microvax 3200	ArcInfo 4.0/5.0	digitizing, mapping, analysis, training
	Microvax 3200	Las 4.0	image analysis, education & research
	Dec st. 3100	Las 4.0	image analysis, education & research
	Dec st. 3100	PV wave	image analysis & 3-D display
	PC 386	Pmap	raster GIS analysis, linking to spatial models
	Dec st. 3100	*Grass	raster GIS
	PC	*ArcInfo	vector GIS
	Mac SE, II	*Map II	raster GIS training & analysis
SEV	PC 386	ArcInfo 3.3	vector GIS
	*Dec st. 5000	*ArcOracle	vector GIS
	=> subcontract some work to NASA Technical Applications Center		
	=> working with computer engineering & Los Alamos on Grass		
VCR	Sun sparc	ArcInfo	vector GIS
	Sun sparc	Erdas 7.4	image processing & raster GIS
	Sun sparc	Grass	raster GIS
	PC 386	Erdas 7.4	scanning, reading tapes