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***NATIONAL CENTER FOR GEOGRAPHIC INFORMATION
AND ANALYSIS***

ANNUAL REPORT

Year 3
(December 1, 1990 - November 30, 1991)

University of California, Santa Barbara
State University of New York at Buffalo
University of Maine

January 28, 1992

NATIONAL CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS

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SUMMARY

The National Center for Geographic Information and Analysis was announced by the National Science Foundation on August 19, 1988, and awarded to a consortium of the University of California, Santa Barbara; the State University of New York at Buffalo; and the University of Maine, for an initial period of five years. Funding began December 1, 1988. The Center's mission reflects the desires of the NSF, as expressed in the solicitation document: to advance the theory, methods and techniques of geographic analysis based on geographic information systems (GIS) in the many disciplines involved in GIS-based research; to augment the nation's supply of experts in GIS and geographic analysis in participating disciplines; to promote the diffusion of analysis based on GIS throughout the scientific community, including the social sciences; and to provide a central clearing house and conduit for disseminating information regarding research, teaching and applications.

This document reports on the Center's third full year of operation. Two new research initiatives have begun, in Visualization of the Quality of Spatial Information, and User Interface Design for GIS. A series of new reports have been released in support of GIS education, including several volumes of lab exercises. Substantial additional support has been generated from external agencies at all three sites, and the Center continues to receive grants of hardware and software. Numerous outreach activities have drawn attention to the existence of the Center, and helped to promulgate its research findings and other contributions, particularly among the software developer and vendor community, and the level of awareness and acceptance of the Center's contributions in the external community has continued to grow. The Center continues to support a high level of external involvement in many of its activities. Finally, the Center has continued to function effectively as a distributed enterprise.

The long-term future of the Center has been the focus of several activities in the third year. In response to requests from the Board of Directors, the Center initiated a strategic planning exercise in February 1991, and presented the results to the Board at its June meeting. The Strategic Plan became one of the inputs to the proposal submitted to NSF in November for a renewal of the Center's Cooperative Agreement from 12/1/93 through 11/30/96, *i.e.* for years 6-8.

1. BACKGROUND

On August 19, 1988, the National Science Foundation (NSF) awarded the NCGIA to a consortium of the University of California, Santa Barbara; the State University of New York at Buffalo; and the University of Maine, with funding of \$1.1 million per year for five years. The third year's operation began officially on December 1, 1990. The decision to establish the Center and the selection process have been described by Abler (*International Journal of Geographical Information Systems* 1: 303-326 (1987)).

NSF's solicitation for the Center in 1987 identified "basic research on geographic analysis utilizing GIS" as the Center's primary mission and suggested five areas as possible research topics: improved methods of spatial analysis and advances in spatial statistics; a general theory of spatial relationships and database structures; artificial intelligence and expert systems relevant to the development of geographic information systems; visualization research pertaining to the display and use of spatial data; and social, economic and institutional issues arising from the use of GIS technology.

In addition to research, the Center was to take steps to "augment the nation's supply of experts in GIS and geographic analysis in participating disciplines; promote the diffusion of analysis based on GIS throughout the scientific community; and provide a central clearinghouse for disseminating information regarding research, teaching and applications". A major peer review of the Center was conducted by NSF in June, 1990, after the Center had been in operation for 18 months.

Much has happened in the field of geographic information and analysis in the four years since the solicitation for the Center was published by NSF, and the consortium's proposal was written. Interest in GIS continues to grow, as indicated by the proliferation of texts and journals, and by attendance at conferences. GIS is moving steadily from an obscure curiosity to an essential tool for geographically related research. We remain convinced, as we were four years ago, that GIA/GIS is of fundamental importance for a broad set of needs and applications, not only in the social and natural sciences, but in planning, management, engineering, and a whole range of areas of human activity. We take the continued interest in GIS technology in the scientific community, and continued and exciting growth in the GIS industry as conclusive evidence. We feel that the reasons for the creation of the Center have multiplied and strengthened significantly in the past four years. The GIS boom that began in the early 1980s continues at full strength, and may even be accelerating. New vendors continue to enter the marketplace with new and exciting products, and education and training programs are proliferating. Despite the recession, parts of the GIS software industry are still reporting growth rates in excess of 40%. GIS technology continues to find new applications and acceptance. Over 4,000 registrants attended the national GIS/LIS conference in Atlanta in October 1991, and regular regional GIS/LIS meetings are now held in most parts of the United States. Over 600 registered for the NCGIA-sponsored First International Conference/Workshop on Integrating GIS and Environmental Modeling in Boulder CO in September 1991.

The 1980s were years of unprecedented economic growth, both in Western economies generally and in the GIS area in particular. GIS is a large and growing industry. Estimates vary, but expenditures world-wide on GIS hardware, software and services are certainly in the billion-dollar range. In its growth, GIS continues to encompass a remarkably diverse set of interests. GIS applications range from resource management through urban infrastructure to emergency response, from political districting to forestry, from local studies to Global Change research. GIS software runs on platforms from PCs to large mainframes, and includes an enormous range of software architectures. Some vendors focus on a single platform, while others offer a single product over the full range of platforms and operating systems. The GIS community includes an extraordinary range of disciplines, from archeology and landscape ecology through geography, forestry to civil engineering, regional science, computer science, remote sensing and even zoology. All of these factors, in our view, make it essential that NSF continue to fund NCGIA as a center for basic research in GIS and its applications in GIA.

In February 1991, the Center began a process of strategic planning at the request of its Board of Directors. A three-day retreat was held in San Diego, and the Center's goals, objectives, programs and structure were reviewed from top to bottom. A new mission statement emerged, reflecting the evolution of the Center and the GIS/GIA field since 1987, and a desire to identify the Center's most fundamental concerns. A new research agenda was written, providing a major updating and reorganization of the plan developed in 1987 for the initial proposal, and organized around three major topics: spatial representation, covering all aspects of the digital representation of geographic information; spatial analysis, including methods of analysis and modeling of geographic systems and processes; and spatial informatics, covering issues of application, diffusion and adoption of GIS technology, and costs and benefits. The following section presents the revised mission statement developed in this strategic planning exercise, and used as the basis for the Center's proposal for funding for years 6 through 8.

1.1 Mission statement

The mission of the National Center for Geographic Information and Analysis is: **the advancement of geographic research of lasting and fundamental significance.** Specifically, we will continue to:

- 1) Advance the theory, methods, techniques and applications of geographic analysis based on geographic information systems (GIS) in the many disciplines and professions involved in geographic research;
- 2) Augment the nation's supply of experts in Geographic Information Systems (GIS) and Geographic Information Analysis (GIA) in participating disciplines;
- 3) Promote the diffusion of analysis based on Geographic Information Systems (GIS) throughout the scientific community and provide a conduit for disseminating information regarding GIS research, teaching, and applications; and
- 4) Interact with individual researchers and organizations on a national and international basis.

As noted above, this mission has evolved to some extent since NSF drafted the solicitation for the Center in 1987, and we believe that it should continue to evolve, responding to developing themes within the research community, while at the same time remaining committed to basic and fundamental research. The GIS industry is large, dynamic and constantly in a state of transformation, and a research center that proposes to interact with that industry, assist its development and encourage its responsiveness to the needs of the scientific community must be similarly adaptable and committed to evolution. We are also cognizant of the need to respond to changes occurring in the geographic and GIS research communities, particularly as the latter matures and defines itself.

Within this overarching mission, the long range goals of NCGIA are to:

- maintain the United States' lead in GIS/GIA technology and applications;
- continue to play a leadership role in geographic research;
- improve, enhance and promote the use of geographic information systems (GIS) and geographic information analysis (GIA) throughout the social and physical science community; and
- improve and enhance the quality of geographic research, education and applications at national and international institutions and organizations.

All of these are long term goals, requiring a sustained level of effort over a period of years if not decades. GIS technology has made enormous strides over the past three years, and there is now much greater awareness of its strengths and limitations in the scientific community. Some of the impediments to the scientific use of GIS that existed three years ago have been removed, due in part to Center research activities. We now have much better designed graphic user interfaces to several GIS products; better understanding of the nature of error in GIS databases and its propagation; better structures for handling data at different scales; and better languages for GIS support of modeling. The concept of using GIS technology to explore data in its spatial context is catching hold. But in other aspects the potential benefits of GIS technology and GIA have barely been realized. We have little idea how to use the power of the technology to improve on human spatial intuition and spatial reasoning. Our models remain based largely on conventional, static and two-dimensional views of data, and have not yet taken advantage of such developments in computer science as object orientation. And systems that handle the vast volumes of data forecast to be available for global change research in the next decade are virtually unavailable. Many of the key organizational and institutional impediments to GIS and GIA remain unresearched. Finally, we have not yet reflected on the meaning of GIS technology to society as a whole.

The following sections expand on each of these four goals in turn, and describe the general components of our continuing strategies for reaching them.

1.1.1. Goal 1: Maintain the United States' lead in GIS/GIA technology and applications

1. Strengthen channels of technology transfer between the research and US industrial communities.

The US GIS software industry is growing rapidly, and currently dominates the international market for these products. However patterns in other areas of US technology suggest that this situation can erode rapidly. A strong argument for center-based

research is that centers can do more than single PIs to foster mechanisms of interaction between the research community and industry, leading to more effective technology transfer. In our first three years, NCGIA built ties with many hardware and software vendors; undertook research sponsored directly by vendors; invited vendors to all of our specialist meetings; and developed cooperative agreements with vendors for longterm research.

2. Increase the overall funding base for geographic research in the US.

The continued success of the US GIS industry requires a solid commitment to basic research. A center can provide effective mechanisms for the development of common research agendas, cooperation and coordination of research efforts, and the building of a strong GIS research community. Several research initiatives are in areas where the Center believes it can play a role in building a strong research community to support the US GIS industry.

3. Identify and create opportunities to expand the United States' GIS and GIA presence within the international community.

As a national center, NCGIA can foster links between the US and international GIS research communities. We have invited foreign scholars to many of our research meetings, maintained international communication networks and newsletters, signed cooperative agreements with many foreign groups and institutions, and contributed to many foreign meetings. A NATO-funded meetings was sponsored by the Center in 1990, and another will be sponsored in 1992.

4. Foster the establishment of creative consortia among academia, government and industry for addressing GIS research and development opportunities in the US.

As an emerging technology, GIS lacks many of the institutions and structures common to more mature fields. It spans many disciplines, and crosses boundaries between many scientific subcultures. Our experience in the past three years has led us to conclude that there is a need for new structures - formal or informal, conventional or unconventional - to foster GIS-based research activity within the broad scientific community. NCGIA proposes to serve as the nucleus for developing such structures over the next few years.

5. Identify and respond to opportunities presented by emerging technologies.

Despite the major cost reductions that have occurred in all forms of digital technology over the past three decades, GIS-based research continues to be constrained by cost. A center can provide access to new technologies, through cooperative agreements with hardware vendors, in ways that are difficult for single PIs. Over the past three years the three NCGIA sites have established major, state of the art concentrations of hardware and software that in themselves constitute major resources.

1.1.2. Goal 2: To continue to play a leadership role in geographic research.

1. To plan, develop and manage a high quality multi-disciplinary research program and the infrastructure required to sustain it.

The process that we put in place to manage Center research has been refined significantly over the past three years, and continues to evolve. The research initiative structure has proven to be an effective means of managing a large and complex organization, and of ensuring strong ties with other researchers and groups outside the Center.

2. To develop and prioritize research agendas in significant areas of GIS and GIA through the initiative process.

The initiative process can make a major contribution to cooperation within the research community in its role as a mechanism for developing and prioritizing research agendas. The research agendas developed at each of our nine specialist meetings to date have been published, as Center reports and in many cases in other publications. As the considered opinions of representative groups drawn from the research community as a whole, they have played a useful role in the development of GIS and GIA research in the past three years. In the future, we propose to seek ways of involving a broader spectrum of the entire geographical research community in the definition of research initiative topics, and to encourage academic reflection on all aspects of the provision, handling and use of geographic information within contemporary society.

3. To produce a steady flow of significant research results of lasting and fundamental value.

It is easy to characterize GIS technology as a fastmoving but essentially shortlived phenomenon. We believe that it would be wrong to focus unduly on the technology itself, since many of the issues raised by the development and use of GIS are fundamental, and will be important long after today's technology is obsolete. We believe that the creation of fundamental research results is in the

best interests of society as a whole, and is the most useful contribution that the research community can make.

4. To maintain the quality of the Center's programs through peer review.

Despite its flaws, peer review remains the best means of maintaining the quality of any research program. Although much GIS and GIA literature is unreviewed, and conference proceedings will continue to be a significant way of promulgating research results, NCGIA is committed to the notion that refereed literature is ultimately of greater value. Periodic peer review by outside consultants and NCGIA's own Board of Directors are important and valuable mechanisms for maintaining quality.

5. To develop and maintain a high rate of timely publication of the Center's research and development results, applications, and education projects.

Unfortunately this objective conflicts to some extent with the previous, since the peer review process for journals takes time, and for this reason the Center will continue to use conference proceedings as one way of promulgating results quickly, while at the same time not seeing this as a substitute for the more valuable refereed route.

6. To maintain active presence in national and international forums, boards and commissions and other deliberative bodies.

Representation on key committees is important to the Center's goals. The Center is currently represented on numerous national and international boards, commissions, program committees *etc.* We are committed to maintaining a high level of representation in the future.

7. To increase involvement of outside participants in the Center's research efforts.

A number of strategies have been followed to date in involving outside participants in Center research and education activities. The specialist meeting is a useful mechanism, as are joint proposals to funding agencies, and direct funding by the Center of outside activities. New mechanisms planned in the future include conferences and joint investigations. However we are aware that there will always be the suspicion that the Center acts as a group of insiders, and that constant efforts are necessary to allay that suspicion.

1.1.3. Goal 3: To improve, enhance and promote the use of geographic information systems (GIS) and geographic information analysis (GIA) throughout the social and physical science community.

1. To present R&D results at a broad range of forums.

Because of the broad range of communities with an interest in GIS and GIA research, and the multidisciplinary nature of the field, we will continue to present results at a range of different forums, including the annual meetings of the Association of American Geographers, the Regional Science Association, GIS/LIS, URISA, the American Congress on Surveying and Mapping, the American Geophysical Union, ORSA/TIMS, the American Association for the Advancement of Science, and many others. The most important international forums for GIS research are the International Symposia on Spatial Data Handling and the AutoCarto series, but GIA results should be directed to a much wider international audience. An international focus for computer science related GIS issues has been established with the NCGIA-initiated Symposia on Large Spatial Databases. The Center will continue to reevaluate the mix of groups represented at different meetings, and to choose meetings appropriate to its overall goals.

2. To produce and disseminate a broad range of publications and multi-media products.

The dissemination of fundamental research calls for publication in high quality refereed journals, but education and outreach goals are better met by a range of alternative channels of publication and media. A number of less conventional methods, including electronic list servers and file transfer, are being used to reach certain important audiences.

3. To develop specialized workshops in advanced GIS and GIA topics.

Workshops are a useful mechanism for disseminating research findings to smaller groups on a more intensive basis. The Center has sponsored a number of successful workshops in the past, and we plan to increase the number of topics covered in the future, as the body of research results grows and dissemination becomes more important.

4. To organize specialized conferences in the use of GIS technology for selected disciplines and groups of disciplines.

The NCGIA-sponsored Boulder conference in September 1991 demonstrated the need for conferences that explore the use of GIS technology in specific targeted areas of research and policy development. Such conferences can be self-supporting (as was the Boulder meeting) and as such are a useful outreach function for a national center. Other more focused conferences include the meeting on GIS and the Social Sciences held in Santa Barbara in March 1991.

5. To promote and participate in the development of national and international standards in all aspects of GIS.

Standards are being called for in all aspects of GIS and GIA. The Center can play a useful role in promoting and supporting efforts to establish standards for the scientific use of GIS, through standard data formats, standards for metadata, or standards for catalogs.

6. To advise the GIS vendor community of ways in which its products could better serve the needs of the scientific community.

The scientific research community often feels that it has little influence over an industry motivated largely by the needs of major commercial customers and public sector agencies. The Center is committed to using its limited influence to promote products aimed specifically at the needs of science, and at the implementation of scientific techniques for policy development.

1.1.4. Goal 4: To improve and enhance the quality of geographic research, education and applications at national and international institutions and organizations.

1. To make maximum use of new technologies and media in disseminating the products of the Center.

Although the Center has initiated several list server discussion groups on electronic mail, the major methods of disseminating publications remain the conventional, expensive and environmentally irresponsible ones of paper and mail. We are moving as much as possible to electronic dissemination, using electronic mail and 'anonymous ftp'.

2. To develop national and international programs of visitors, lectures, scholarships, fellowships and exchanges.

Support for visitors is an important way of maintaining a critical mass of active researchers at each Center site. Facilities developed during the first years of the Center's operation provide an increasingly attractive location for visiting scholars.

3. To develop forums for the general GIS community for discussion of issues of interest.

The GIS-L computer network discussion list has provided a popular forum for lively, international discussion, and we plan to continue supporting it in the future.

4. To provide guidance, methods and standards for the development of educational and training programs.

An important guiding principle in developing Center educational materials, including the Core Curriculum project, has been that they should be presented as catalysts for discussion and revision, rather than as ideal, prescriptive products. A center can marshal the resources to assemble such strawmen, and facilitate the subsequent discussion, in ways that individuals cannot. This has been especially important in GIS, which continues to lack alternative institutional structures.

5. To enhance the range of educational opportunities available through NCGIA.

The Center is committed to continuing efforts to provide more educational opportunities in GIS and GIA, through its own programs, materials provided to the educational community, and workshops offered at appropriate opportunities.

6. To direct government, industry and educational institutions to available sources of information and expertise in GIS.

Given the various clearinghouses and online information services already in existence, and the costs associated with providing such functions, the Center has focused primarily on providing access to information in support of scientific applications of GIS and GIA, and of fundamental geographic research. Past and planned activities include compilation of research bibliographies and general survey articles and texts. The Center will continue to promote the development of other clearinghouse activities in GIS and

GIA.

7. To develop and disseminate materials to support GIS education and training.

This has been a major feature of education activities over the first three years. The education section of this report includes specific discussion of recent activities in this area.

8. To explore the use of GIS technology in the high school and elementary school curricula.

This will be a significant part of the Center's education activities in the coming year.

2. SUMMARY OF MAJOR ACTIVITIES

A. Research

Research in the Center takes place within the framework of a series of research initiatives. Each initiative begins with a specialist meeting attended by professionals from outside the Center, in which the most important problems in the subject area of the initiative are identified and ranked and a feasible research agenda for the initiative is defined. Research continues intensively for 18-24 months with teams of faculty (NCGIA or other), postdoctoral fellows, or advanced graduate students, as well as representatives from private industry or government agencies, working in teams on specific problems. Specialist meeting participants and other interested individuals are kept informed of the progress of research through newsletters, symposia, and presentations at conferences. The completion of an initiative is marked by the holding of a national forum to present the research results. Results are also announced in articles in refereed journals, presentations at conferences, bibliographies, algorithms or models for analysis, NCGIA Technical Papers, and short courses or workshops. Completion marks the end of significant financial support from NSF funds, but does not imply that the topic has been exhausted or that the Center's interest in the topic has ended. Rather, completion may signal the need to redefine the research agenda, or to initiate related research in new directions.

During the third year two initiatives were begun, leaving a total of six active initiatives at the end of year 3:

4. *Use and Value of Geographic Information*. Co-Leaders: Harlan Onsrud (Maine), Hugh Calkins (Buffalo). Specialist Meeting: Maine, May 1989.
5. *Design and Implementation of Large Spatial Databases*. Co-Leaders: Terence R. Smith (Santa Barbara), Andrew U. Frank (Maine). Specialist Meeting: Santa Barbara, July 1989.
6. *Spatial Decision Support Systems*. Co-Leaders: Paul J. Densham (Buffalo), Michael F. Goodchild (Santa Barbara). Specialist Meeting: Santa Barbara, March 1990.
7. *Visualizing the Quality of Spatial Information*. Co-Leaders: M. Kate Beard (Maine), Barbara P. Battenfield (Buffalo). Specialist Meeting: Maine, June 1991.
12. *Integration of Remote Sensing and GIS*. Co-Leaders: John E. Estes, Jeffrey L. Star (Santa Barbara). Specialist Meeting: Sioux Falls, December 1990.
13. *User Interfaces for GIS*. Co-Leaders: David M. Mark (Buffalo), Andrew U. Frank (Maine). Specialist Meeting: Buffalo, June 1991.

Several other initiatives are in various stages of planning, and they and the completed initiatives are included in the following discussion where significant activities have occurred.

Initiative 1: Accuracy of Spatial Databases (completed Fall 1990). This initiative has focused on methods and techniques for dealing with error and uncertainty in geographical data. Although the initiative was completed in 1990, several activities related to I1 continued throughout 1991.

A group of researchers at Santa Barbara led by David Lanter worked during early 1991 on the development of a lineage system to track database uncertainties through GIS processes. As part of this work, doctoral candidate Howard Veregin extended his previous results on error propagation. Paul Sorensen investigated error propagation in the determination of viewsheds with Lanter in the summer of 1991. The stochastic process model developed during the initiative for representing uncertainty in area class maps was implemented in the GRASS raster GIS package by Yang Shiren and Lin Chih-Chang, and will be distributed over the GRASS network. Also at Santa Barbara, Yang Shiren, Shu Shourong and Lin Chih-Chang continued their efforts to build a prototype global GIS using the triangular tessellation proposed by Geoffrey Dutton and the 3D capabilities of the IBM RS/6000 workstation provided under the IBM-NCGIA Joint Study Agreement. At Maine, Kate Beard and David Pullar continued their work on modeling error in polygon operations, including overlay, and David Zhang wrote two papers on error in GIS.

Michael Goodchild and Peter Fisher (Kent State University) presented a workshop based in part on the results of the initiative at the Association of American Geographers meetings in Miami in April 1991, and the workshop was repeated at the ESRI Users'

Conference in Palm Springs in May. Goodchild was the keynote speaker at a two-day symposium on spatial database error in Melbourne, Australia in June.

At Santa Barbara, a contract on the accuracy of forest mapping using GIS was completed for the California Department of Forestry and Fire Protection, and a new contract was awarded under which UCSB will organize a task force to evaluate the accuracy of the current CDFFP mapping project. Goodchild participated in a workshop organized by Oak Ridge National Laboratory in August to provide guidance on the accuracy of NOAA coastal zone wetland mapping, and has been appointed IGU representative to the ICA Commission on Spatial Data Quality.

Much of the momentum generated by Initiative 1 will be transferred to the new Initiative 7 on visualizing data quality, since visualization provides a practical means of communicating information on error models and their parameters.

Initiative 2: Languages of Spatial Relations (completed Fall 1990). Major work on spatial languages at NCGIA Buffalo ended with the NATO Advanced Study Institute in Spain (July 1990) and with three Buffalo-authored papers presented at the Fourth International Symposium on Spatial Data Handling in Zurich (also July 1990). Since then, most work has been directed toward one stream that developed from Initiative 2 into a separate new initiative, namely issues of the user interface (Initiative 13). At the University of Maine, Max Egenhofer has further developed the systematization of topological relations. Andrew Frank first investigated cardinal directions as an example of a metric spatial relation and then extended the study to include qualitative distance relations, *e.g.* 'far' or 'near'. Both Egenhofer and Frank start by using methods from relation algebra.

In addition, work on prototypical meanings of prepositions continues at Buffalo as "outgrowth research", as yet unfunded. David Mark is studying the meanings of prepositions in several languages, and has developed a new model of their meaning and cross-linguistic expression, based on Rosch's 'prototype' theory of the internal structure of cognitive categories. Mark has collected data on English, and has analyzed Spanish data collected by Michael Gould in Ecuador. Another Ph.D. student at Buffalo, Normand Bergeron, has collected large samples of 'best examples' for some French prepositions from subjects in Montreal and in France. Preliminary analysis supports a strong prototype model: for example, more than half of the subjects have given "the [object] is on the table/desk" as the prototype for *on* (English), *sobre* (Spanish), *sur* (French), and *auf* (German).

The book arising out of the I-2-sponsored NATO Advanced Study Institute *Cognitive and Linguistic Aspects of Geographic Space*, edited by David Mark and Andrew Frank (Maine), was published by Kluwer Academic Publishers in Fall 1991. An I-2 related panel session on "Representation of Geographic Space" has been organized for the 1992 Association of American Geographers meeting.

Initiative 3: Multiple Representations (completed Fall 1990). The term "Multiple Representations" refers to changes in the geometric and topological structure of a digital object that may occur with the changing resolution at which that object is encoded for computer storage, analysis, and depiction. Cartographic and digital data arguably provide only a sample of the geographic features they are intended to represent. As discrete approximations of a continuous reality, each cartographic object may capture at most a subset of its geographic counterpart. The resolution at which features are captured by digital encoding methods will often bias the amount and types of details about the features that are encoded. The implications for geographic information and analysis formed the basis for prioritizing a research agenda.

The initial scope of this initiative encompassed both database issues and problems in map generalization, and previous annual reports discuss various projects in both domains. In the past year, research progress has focused on the map generalization problem, with particular emphasis on automatic scale-changing.

Following the very successful Syracuse Symposium, reported in the 1990 Annual Report, collaborative research led to two paper sessions at the Anaheim GIS/LIS'90 meeting in late November. Work continued to publish an edited volume, *Map Generalization: Decision-Making for Knowledge Representation*, edited by Barbara Buttenfield and Robert McMaster, and drawn from the symposium papers. Chapters from thirteen authors were received and edited in January, and the manuscript was completed in early February. The book was published by Longman in September 1991.

One research project in particular has been pursued in detail this year, and focuses on inventory of existing topographic map series. The goal is to determine if cartographic symbols are represented and generalized in consistent manner across 4 map scales. The purpose of the inventory is itemize object behaviors during scale change and to develop queries to the database to determine rule formation and consistency. Buttenfield collaborated with Jean-Claude Muller (ITC, The Netherlands), during Muller's two month residence in Buffalo during the late fall of 1990. During the 1991 spring semester, a graduate seminar at Buffalo refined the research design. Results of this seminar were submitted in August for inclusion in the Proceedings of the Atlanta GIS/LIS '91 meetings. One

student in the seminar, Michael Leitner, has undertaken thesis research to inventory Austrian topographic maps. His work should be completed during the spring semester 1992.

Research initiative 3 was formally completed in Fall 1990. This does not mean that the research has terminated, but rather that a momentum in multiple representations research has developed throughout the general community, obviating the need for NCGIA to serve as catalyst. Academics, federal agencies and private sector vendors are working in what is variously termed 'differential generalization', 'automatic scale-changing', and 'rule-based generalization'. Results are being presented in conference proceedings and in the refereed literature. At NCGIA, research in this area continues as a transition to Initiative 8, as described below.

Initiative 4: Use and Value of Geographic Information (to be completed in early 1992). Goals of this initiative have been to improve models for tracking the use of geographic information, to expand methods for assessing the value and benefits of geographic information, to formulate methods for better understanding the factors and processes affecting acquisition, implementation, and utilization of geographic information innovations, and to advance methods for modeling the diffusion of geographic information technologies.

Results of the nationwide survey of local government GIS users are continuing to be analyzed by researchers at Maine to identify the critical factors and processes for the class of users tested, to formulate a model of adoption success incorporating acquisition, implementation, and utilization components, and to test the efficacy of the theoretical framework in evaluating the use and value of geographic information innovations. Extending from the Onsrud/Pinto survey results, Bijan Azad (PhD candidate-MIT) is pursuing several theory-focused case studies.

Harlan Onsrud and Jeffrey Pinto have co-authored three recent journal articles: "Diffusion of geographic information technologies" (*International Journal of Geographical Information Systems*); "Case study research methods for geographic information systems" (*Journal of the Urban and Regional Information Systems Association*); and "Evaluating correlates of GIS adoption success and the decision process of GIS acquisition" (under review for *URISA Journal*). A proposal has been sent to the editors of *URISA Journal* to consider publication of four I4 articles as a group in a "special issue", which would incorporate reports of progress from several additional researchers on use and value issues.

A nation-wide case study research project to test a series of technology transfer theories in GIS operational environments is under way. The project is a joint effort of NCGIA Initiative 4 and the URISA Education and Technology Transfer Special Interest Group. To date, several individuals have taken up the call and are using the methodology presented in the article to make observations of the GIS operations in: (1) Cumberland County Planning Department, North Carolina; (2) Town of Middleton, Wisconsin; (3) Municipality of Burnaby, BC; (4) City of Corpus Christi, Texas; (5) a major forest resources company in Maine; (6) City of Worcester, Massachusetts; and (7) a municipality in Indiana. All of these people have agreed to carry out the work and submit their study results in journal article format before the end of summer 1992. Numerous others have expressed interest but have yet to commit. Depending on the research results and the quality of the reports, we intend to produce a major report or book.

Harlan Onsrud is organizing a series of presentations sponsored jointly by NCGIA Initiative 4 and the URISA Education and Technology Transfer SIG which will take place during URISA '92 in Washington, DC. There will be organized sessions on: (1) "What can we learn from GIS case study research?", Chair: Jeffrey Pinto; and (2) "Knowledge Gained and Future Work: Research in the Use and Diffusion of Geographic Information Technologies", Chair: Harlan Onsrud.

The primary wrap-up session for Initiative 4 will take place at the NATO Advanced Research Workshop on "Modeling the Use and Diffusion of Geographic Information Technologies" in Sounion, Greece, April 8-11, 1992. The co-directors of the workshop will be Ian Masser, ESRC Regional Research Laboratory, University of Sheffield, and Harlan Onsrud. A proceedings volume will be published in due course.

Initiative 5: Very Large Spatial Databases (VLSDB) (began July 1989). Work on Initiative 5 has continued at Santa Barbara: Terence Smith is leading an ongoing investigation of the design of an object based data model and a deductive language for applications involving spatio-temporal objects. The key objective is to provide a theoretical basis underlying most GIS and spatial database applications. Other researchers involved in the project include A. Voisard of INRIA, France and Dr. R. Ramakrishnan of the Department of Computer Science at the University of Wisconsin. An NCGIA technical paper on this data model and language have been published. The report includes a detailed description of the data model and the language, both in terms of syntax and semantics. Three detailed applications are worked out in the language. A first presentation of the work was made at the GOODS workshop in Capri in May, 1991.

Nehal Trivedi and Smith have written an NCGIA technical report, "A Schema for Metadata for Large Spatial Databases". The schema is relatively simple and easy to implement, and extends the methods employed in relational databases for handling metadata. The report includes a worked example of the application of the schema for a database of environmental data. The Center is represented on the ASTM committee on GIS standards, which has produced a draft metadata standard for spatial data, by Hugh Calkins.

Work at Maine on I5 topics progressed primarily with the formalization of spatial relations which are necessary for query languages. This is a topic which was judged to be important during the specialist meeting. Similarly, Renato Barrera and a graduate student worked on 'robust query evaluation', a formalization of methods to have queries evaluated with a progressing level of detail. Frank investigated new spatial query languages particularly suitable for the exploratory access geoscientists need, published at a European workshop on Database Management Systems for Geographical Applications held in Capri, Italy in May 1991. He proposed an iconic language using "data cubes" (for data sets) and "maps" (for the graphical presentation of data sets) so that "data cubes" can be explored by dragging them over "maps". This separation is in concert with the results of the design of spatial SQL where separate languages were used to formulate the queries and display instructions.

Initiative 6: Spatial Decision Support Systems (began March 1990). This initiative examines the possible role of GIS and associated techniques in the decision-making process, emphasizing the notion that GIS only provides rudimentary support for decision-making and that more sophisticated methods of decision support are required. Four research themes emerged from the specialist meeting, namely: optimal schemas for decision support in areas of ill-defined problem-solving; modeling and data requirements for SDSS; technology and the implementation of SDSS; and user requirements and organizational issues. The issues defined involve a wide range of application areas although the research domains discussed at the specialist meeting were narrowed to marketing, retailing, location theory, and socioeconomic models.

The first edition of the I-6 newsletter was compiled by Bruce Ralston (University of Tennessee) and mailed to all persons on the initiative mailing list. The working bibliography, distributed at the I-6 Specialist Meeting, was expanded and published as *NCGIA Technical Report 91-9, "Spatial Decision Support Systems: A Bibliography"*, by Michael Gould and Paul Densham. Three participants in the I6 Specialist Meeting — Gerard Rushton (San Diego State University), Marc Armstrong (University of Iowa) and Paul Densham (SUNY at Buffalo) — are co-authors with Suranjan De (University of Iowa) of a forthcoming book entitled *Spatial Decision Support Systems: Principles and Applications* (Oxford University Press).

Paul Densham and Marc Armstrong (University of Iowa) received funding for a proposal to NSF entitled "Improving Human-Computer Interaction in Locational Decision Making". The award of \$99,810 is for the period from June 1991 to December 1992, and is from three programs in NSF: Geography and Regional Science, Information Technologies and Organizations Program in the Directorate of Computer Science and Engineering, and the Computational Life Sciences initiative in the Division of Instrumentation and Resources. The outgrowth research will examine several elements of the research agenda developed at the I-6 Specialist Meeting. Parallel computing architectures and scientific visualization principles will be employed to improve human-computer interaction in the solution of location-selection problems. Research foci are the development of parallel location-selection algorithms, tools to enable decision-makers to visualize solutions generated by these algorithms, and implementation strategies that integrate the algorithms and visualization tools.

Hugh Calkins, Paul Densham, and four faculty from the Great Lakes Program at SUNY at Buffalo, have secured funding from the Environmental Protection Agency for the development of a SDSS for exposure-effects analysis of contaminants in the lower Great Lakes. Funding over three years totals approximately \$1.6 million. Research concerns the development of a sequence of exposure-effect models and their integration with a GIS.

Stewart Fotheringham and Paul Densham are investigating the effects of the modifiable areal unit problem in linked spatial models. David Wong visited the Buffalo site in early March to work with Fotheringham and Densham, and also spent the month of June in residence at Buffalo working on similar research.

The First International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling, co-organized and co-sponsored by NCGIA, was held in Boulder, Colorado from September 15-19, 1991. The emphasis of this conference and workshop was on linking process models and GIS, and to achieve this the meeting sought to bring together users of GIS and modelers in the environmental field. This event is both an outgrowth of and response to the narrowing of focus of I-6 to location, marketing and retailing applications of SDSS.

Two sessions on I-6 research have been organized for the 1992 Meetings of the Association of American Geographers in San Diego in April. These sessions are co-sponsored by the AAG Specialty Groups on GIS and Mathematical Models and Quantitative

Methods, and by the NCGIA. In the first session, six papers on design and organizational issues will be presented with a further five on SDSS for routing and location selection in the second. A one-day workshop on SDSS also has been organized for the meetings.

The working bibliography, distributed at the Initiative Specialist Meeting, has been published as NCGIA Technical Report 91-9, "Spatial Decision Support Systems: A Bibliography" by Paul Densham and Gerard Rushton. David Willer (SUNY Buffalo) in his Master's project developed a prototype SDSS for bank branch location planning, integrating a commercially available microcomputer based GIS (TransCAD) with a location-allocation package. This is available as NCGIA Technical Report 90-9, "A Spatial Decision Support System for Bank Location: A Case Study". Stewart Fotheringham and Paul Densham are investigating the effects of the modifiable areal unit problem in linked spatial models. Census block groups for Buffalo have been aggregated using 20 different zonal patterns at each of six levels of aggregation, yielding 120 data sets. A cohort component model ages the population over four time periods for each data set. Location-allocation models are used with the segment of the population aged 65 years and over to locate elderly day-care facilities. Analyses are under way to determine the effects of using different levels of aggregation on the results of the models.

At Santa Barbara, David Lanter's group is developing a series of alternative taxonomies of GIS functions and tools, and Lanter is researching the use of data lineage information in spatial problem-solving. A project funded by the US Forest Service (Principal Investigators David Lanter and Richard Church) is building an SDSS for timber allocation by adding a spatial component to the FORPLAN optimization model.

Initiative 7: Visualization of the Quality of Spatial Information (began June 1991). The quality of spatial information and spatial information products is multidimensional and complex, and clearly, it varies both spatially and temporally. Communicating this potentially large and complex pool of information to users is a challenge. Visualization has recently been proposed as a technique for making complex information more comprehensible. A primary research objective of this initiative is thus to explore the tools of visualization for communicating the many dimensions of geographic data quality to users in meaningful ways.

The I-7 specialist meeting was held June 8-12, 1991, in Castine, Maine. Thirty-five participants attended. *NCGIA Technical Report 91-26* describing the Specialist Meeting and its prioritized research agenda is printed and in distribution.

In preparation for the specialist meeting, a panel on "Visualizing the Quality of Spatial Information" was held at the Baltimore AutoCarto 10 meetings in late March. Panelists included Nick Chrisman (University of Washington), Ferko Csillag (Syracuse University), Robin Fegeas (US Geological Survey), Alan MacEachren (Penn State University) and Alan Saalfeld (Bureau of the Census). Barbara Battenfield chaired the panel. The panel provided an open forum for the research community to discuss impediments and prioritize researchable topics for the initiative.

During the summer, two sessions related to I-7 related research were organized for the 1992 AAG meeting in San Diego. Dan Griffith, Syracuse University, has organized a session on error modeling and visualization, with presentations by Robert Haining (University of Sheffield), Giuseppe Arbia (University of Rome), Subash Lele, and Art Getis (San Diego State University). Barbara Battenfield has organized a session on cartographic aspects of data quality representation with presentations planned by Mark Monmonier (Syracuse University), Alan MacEachren (Penn State University) and Matt McGranaghan (University of Hawaii).

In October 1991 the editor of the international journal *Cartographica* agreed to publish a special issue on cartographic aspects of visualizing data quality. The issue will include four or five invited papers. Barbara Battenfield will be guest editor. Author manuscripts are due by March 1992, to undergo blind review; the issue is expected to appear in January 1993.

The first issue of the I-7 newsletter "VQSD" was distributed to the specialist meeting participants and an extended mailing list of interested individuals. Geoffrey Dutton edits the newsletter, which will appear twice per year and contain brief articles on research, conferences, and other activities related to the initiative topic within and beyond the Center.

In November, a special session devoted to data quality issue was held in Ottawa, Canada, at a conference on spatial data hosted by Statistics Canada. Preparations were also completed for a paper session on Visualization and GIS at the Interface '92 Conference, to be held in March 1993 in College Station, Texas. The conference is jointly sponsored by several organizations, including IEEE and the American Statistical Association.

Other projects are underway to develop the initiative and expand interest among members of the external community. An annotated bibliography is being compiled jointly by graduate students at Maine and Buffalo. The list explores literature across disciplines, considering notions of data quality and visualization concepts and techniques from statistics, scientific computing, medical

imaging, automated manufacturing, dynamic process analysis, and graphic design. MA thesis research to develop hypermedia tutorials on data quality was completed by Tom Kress at Buffalo. Victor Wu is developing a toolkit of data quality representation techniques to incorporate with GIS software as a part of his doctoral research effort at Buffalo.

At Santa Barbara, Yee Leung of the Chinese University of Hong Kong and author of a text on applications of fuzzy sets to geographical data, was a visiting researcher for three months in the summer of 1991. With Lin Chih-chang he developed a series of methods for display of fuzzy classifications of land cover, and these are being integrated with the stochastic process model of error in area class maps to support the use of fuzzy classifications in GIS. Diane Schweizer is completing a study of the visualization of data uncertainty in choropleth maps, within the framework of multivariate choropleth mapping techniques.

At the University of Maine, Sarah Clapham and Kate Beard have been working on a framework which seeks to make logical connections between data quality components and visual variables for displaying those components. This work is based on formal specifications of data quality components including positional accuracy, attribute accuracy, and currency and a selected set of visual variables including color, shape, and size. Scales of measurement are used as the link between the behavior of a quality component and behavior of a visual variable.

Kate Beard is working on the use of reference grids as a visual display tool for different quality components. The reference grid is a mesh of uniform cells which can be registered and displayed as a backdrop to the data. The size and configuration of the mesh is used to show different quality variables associated with the data. The uniform grid acts as a visual reference point. Distortion of the grid can be used to show the location and magnitude of changes in the quality of the data. For example, deviations from the uniform pattern will visually indicate locations and magnitudes of errors in the data. Conversely improvements in the uniformity of the grid can indicate improvements in the quality of some component.

Work is also continuing at Maine on the Data Quality NoteBook, a Hypercard stack which provides a visual and animated tutorial on spatial data quality. The Data Quality Notebook uses the metaphor of a small spiral notebook in which users can flip through the pages to find the information they need. It provides definitions of quality, spatial data quality, and spatial data quality components. The main purpose of the Notebook is to track specific data collection methods and illustrate how collection and processing activities affect spatial data quality. Two case studies in the notebook, remote sensing and soil mapping, document the steps of data collection and compilation into products which could be incorporated in a GIS. A matrix is used to show how each compilation step affects positional accuracy, attribute accuracy, completeness, and logical consistency.

Initiative 8: Formalizing Cartographic Knowledge (to begin 1993). Research and development of automated mapping capabilities requires formal and consistent guidelines. Examples of such guidelines may be found in cartometric algorithms, or generalization formulae such as the Radical Law. Guidelines governing some cartographic tasks, *e.g.* the choice of map projection, or the location of place names, have also been formalized as expert systems. Many rules for map design and production exist in the published literature, in rule bases that have already been compiled (such as the one at the US Defense Mapping Agency), and in specifications guiding map compilation in the public and private sector. Rule interaction for name placement on maps has already been a focus of Center research.

However, the solutions to these problems have not been complete or general, and solutions to other aspects of map design, *e.g.* selection of color progressions or tolerance value modification, have eluded even partial solutions to date. Many cartographic operations have aspects that are intuitive or involve specialized expertise, and are difficult to formalize. The lack of formal cartographic knowledge impedes implementation of fully automated mapping.

I-8 will build on results from I-3 (map generalization and issues of scale and resolution) and I-7 (visualization issues), and also will draw on (and contribute to) I-13 (interface for the prototype) and I-6 (use of graphics for spatial decision support). The initiative will focus on non-thematic maps, which are the most standardized products in terms of data content, quality, and presentation. The goal of the initiative is development of a test-bed for the formalized knowledge, rather than development of a single expert system to make maps. The initiative is currently in the planning stages, although some research activities are currently under way.

Researchers at Buffalo have undertaken a pilot study to inventory portions of European topographic maps. The goal is to demonstrate that a multi-scale inventory can be implemented in a relational database, to determine rules and inconsistencies in the design and generalization of map symbols. The determination of robust rules will reduce the cost of map production and improve consistency and quality control of digital map products. Additionally, formalized rules can be implemented as design defaults in GIS and SDSS software, to reliably display data patterns upon which spatial inference and spatial decision-making are based.

Phases of research in the investigation include collecting the inventory, organizing the information in a relational database, and querying the database. Queries are expected to compare map treatments between mapping agencies, to determine inconsistencies in cartographic principles that may prove difficult to formalize. A second expectation is to identify map scales at which feature geometry may be expected to undergo sudden metamorphosis during generalization. A third goal of the investigation is to query the database to guide design of prototype rules for cartographic behavior and interaction with other objects.

Barbara Buttenfield made conference presentations on a computerized inventory of European topographic maps to determine rules formalizing design procedures at the Bournemouth ICA meetings in September and at the Atlanta GIS/LIS meetings in November. Rules can be determined through inventory of maps across (conventional ranges of topographic and cadastral) scale, subject domain (hydrography, terrain etc.) and mapping task (abstraction, compilation, symbolization, production). Initial research has already begun as an investigation, with participation by Barbara Buttenfield, NCGIA-Buffalo, and Jean-Claude Muller, ITC, Netherlands). The goal is to ascertain consistency of cartographic treatment within agencies, and to generate prototype rules guided by results of the inventory.

An International Cartographic Association (ICA) Working Group on Map Generalization was formed at the Bournemouth ICA meetings in September, with participation of ICA members from France, Germany, UK, USA, Switzerland, Poland, and Spain. Susan Waldorf (Intergraph Corporation, USA) will chair the Working Group for its first year of activities.

Frank Fico, at Buffalo, completed his Master's thesis research in August on generalizing DMA's Digital Chart of the World, a comprehensive digital cartographic database for GIS small-scale mapping purposes. The thesis will be published as *NCGIA Technical Report 92-2*. In other Buffalo research, Feibing Zhan, a doctoral student, has been implementing rules for map design in expert system shells to compare the utility of various systems for map design formalization. This fall, he has begun a comparison of CLIPS and Nexpert-Object.

Jean-Claude Muller and Barbara Buttenfield are submitting a proposal to NATO to host an Advanced Research Workshop in Germany on Generalization early in 1993. In addition to Muller and Buttenfield, the organizing committee includes François Salgé (France), Bernd Povitz (Germany) and Christopher Board (UK).

Initiative 9: Institutions Sharing Geographic Information (to begin February 1992). Geographic information is used to satisfy many needs. These include the needs of those who make location-related decisions (*i.e.* all levels of government and the private sector), scientists and educators. Often, satisfaction of these needs requires knowledge of and access to data and information held by others. This initiative is organized around the issues and problems of sharing geographic information and the technologies which enable this sharing to be made more effective. The three primary components of the research framework include: theories of individual and organizational behavior (particularly their relevance in understanding impediments and incentives to the sharing of information); the arenas among which sharing of spatial data occurs, could occur, or could be enhanced; and observations of the process of spatial data sharing in existing settings. Ultimately, these three components must be brought together to produce models of behavior in regard to spatial data sharing. These results, in turn, should be useful in developing normative proposals for successful spatial data sharing in specific situations.

Harlan Onsrud (Maine) and Gerard Rushton (San Diego State University) led a planning meeting for Initiative 9 in April 1991 in Chicago. The goals of the initiative are to determine the set of organizational issues that can aid in inter-organizational sharing of geographic information, to evaluate those behavioral issues that can help or hurt the flow of geographic information across and among agencies, and to assess that body of legal knowledge important to the sharing of geographic information.

Gerard Rushton and Harlan Onsrud are organizing a specialist meeting from February 27-29 in San Diego, CA. The subject matter was set out in a pre-conference issue paper written by a ten member planning committee drawn from several universities. A Call for Abstracts was posted on the GIS-L list server and was distributed widely in various GIS and MIS related publications. The response was excellent: 47 submittals were reviewed by six referees, resulting in 24 accepted papers.

Initiative 10: Spatio-Temporal Reasoning in GIS (to begin 1993). Spatio-temporal reasoning is so common in humans' daily lives that one rarely notices it as a particular concept of geographic analysis. Far more apparent are spatial reasoning problems in the derivation of new spatial knowledge in computerized systems, *e.g.* about topological relations, distances and directions, and connectedness in GIS and other areas such as robotics, vehicle guidance/navigation, and way finding. Spatio-temporal reasoning is a new research area and current methods to infer spatio-temporal information are limited. Major efforts are related to vision, particularly deducing 3D information from 2D models, and only limited resources deal with geographic space and its temporal aspects. The goal of this initiative is to rectify this deficiency and to deal with qualitative information in geographic space, together with its temporal dimensions. Cognitive theory predicts that results from daily experience with different spatio-temporal concepts are integrated and further used metaphorically to reason in other circumstances. Human experience and perceptual cognition will be

explored to guide the construction of abstract formal systems and to assess the formalized systems for their usefulness.

The initiative will concentrate on geographic space and time related to objects in geographic space. It intends:

- to provide computational frameworks, within which geographic phenomena and their temporal changes can be simulated;
- to formalize human reasoning processes about geographic space; and
- to examine (verify/dismiss/refine) computational reasoning frameworks with observations from experiments about human spatial and temporal perception and cognition.

The initiative leaders, Reginald Golledge (Santa Barbara) and Max Egenhofer (Maine), have arranged to cooperate with a conference on spatio-temporal reasoning, to be held in Pisa, Italy in Fall 1992 (September 21-23). The conference title is "GIS - From Space to Territory: Theories and Methods of Spatio-Temporal Reasoning" and it is expected to have considerable input from geographers interested in human spatio-temporal processes and modeling. Besides the co-leaders, NCGIA researchers Andrew Frank (program co-chair), Helen Couclelis, Michael Goodchild, David Mark and NCGIA Board member William Skinner are on the program committee.

The NCGIA will make use of this concentration of international and US researchers to hold a 2-day workshop immediately afterwards at the same location, to which researchers present at the conference with a strong interest in the initiative topic will be invited. This workshop will function as the pre-specialist meeting, similar to the successful pre-meetings for I2 and I13 in Buffalo and Seattle, respectively. The primary goal of this workshop will be to discuss relevant research areas in spatio-temporal reasoning and to set the agenda for the specialist meeting. Results of this workshop will be published as an NCGIA technical report and made available to interested researchers. The specialist meeting is planned to be held in the US, six to nine months after the conference in Pisa.

Suchi Gopal (Boston University) is organizing a special session at the AAG 1992 annual meetings on "Geographical Reasoning: Research Issues". It will include presentations by Andrew Frank ("Temporal Data and Temporal Reasoning for GIS") and Max Egenhofer ("Spatial and Temporal Relationships in GIS Query Languages").

During the Fall semester 1991, Max Egenhofer and Andrew Frank organized a graduate seminar on Spatial Reasoning. Eleven graduate students participated. The course material covered different approaches in spatial and temporal reasoning, as they have been promoted by geographers, computer scientists, and psychologists. Particular emphasis was put on qualitative aspects (as opposed to quantitative geometric approaches using Euclidean geometry). Reading material included publications by Cardenas, Davis, Kuipers, McDermott, Riesbeck, and Stevens. Each graduate student selected a research topic within the realm of spatio-temporal reasoning on which they worked during the semester. The final reports, due at the end of the semester, will be summarized in an NCGIA technical report. The topics covered included: the formalization of different ways of reasoning about the combination of cardinal directions (north, east *etc.*) and approximate distances (*e.g.* near, far); the implementation of a hierarchically structured universe, within which it is possible to reason about cardinal directions and approximate distances with a reduced amount of knowledge; the detection of topological inconsistencies from the description of a scene of objects by a number of binary topological relations; reasoning about topological changes if the objects are moved; the formalization of properties of very simplistic spaces, which we call synthetic experiential spaces; deriving information about geographic space by combining different spatial concepts; and the formalization of a multi-layer highway-navigation system in geographic space for different tasks - planning, giving directions, and driving. Three extended abstracts based on interim results have been submitted to the Spatial Data Handling Symposium next August.

Max Egenhofer has developed a method to describe formally a sequence of changes in the topology of spatial relations. In cooperation with Burkhard Schaffrin (OSU), this method will be applied in an attempt to make adjustments of overdetermined topological information without the need for metrical information. Andrew Frank has formalized a hierarchically regionalized universe, within which we can simulate the misjudgments of directions between cities that humans typically make. This system is useful for a number of spatial reasoning approaches, *e.g.* to study various spatial reasoning approaches; to compare the accuracy of reasoning schemas that are based on a very limited amount of spatial information (and thus in accordance with assumed limitations of the human brain) with accurate computations based on coordinate locations. It may also be used to model aspects of economic models and formalize border regions with their spatial situation.

Initiative 11: Space-Time Modeling in GIS (to begin 1993). In this initiative we propose to focus on temporal and spatial aspects of environmental modeling in the global change context. Much of the current research in this area involves attempts to apply models

across a wide range of scales and the closely related problems of integrating data from a variety of platforms with very different spatial and temporal resolutions and sampling rates. The close intertwining of process scale with modeling and data analysis procedures raises a variety of geographical issues which have not always been fully anticipated by researchers moving into global change research. We are interested in examining the role of GIS, both as a set of specific products and on a more general, conceptual level, in the implementation of large-scale modeling, data gathering, and analysis schemes.

Initiative 12: GIS and Remote Sensing (began December 1990). Remotely sensed images continue to offer a cost-effective and popular source of data for GIS. At the same time GIS data is increasingly used as a means of improving image classification. However the coupling of the two technologies raises many questions. Following planning meetings in May and August 1990, the specialist meeting was held December 3-6, 1990 in Sioux Falls, SD, at EROS Data Center (USGS). Discussion centered on five topics for the integration of remote sensing and GIS: institutional issues, data structures and access, data processing flow, error analysis, and future computing environments. Papers on each of these five themes were presented for discussion at the specialist meeting, and later revised to appear as a special issue of *Photogrammetric Engineering and Remote Sensing* in June 1991.

A special session was organized by NCGIA on the work of I-12 at the Baltimore 1991 ACSM/ASPRS Annual Convention. Eighteen papers were presented and a special proceedings volume has been edited by Jeffrey Star and published by ASPRS. A panel on I-12 was held at the April 1991 AAG meetings in Miami. John Estes, Jeff Star, Dale Quattrochi (NASA/Stennis) and Doug Stowe (San Diego State University) spoke about the work under way, and the panel drew a good reaction from the audience with particular interest from people involved in the Coastwatch project. John Estes, Jeff Star (UCSB) and Nick Faust and Andrew Baffes (ERDAS) organized a computer workshop on "Understanding the Integration of Remote Sensing and GIS" in Milwaukee on June 24-26, 1991. Manfred Ehlers (formerly of NCGIA/Maine and now from ITC) and Nick Faust (Georgia Institute of Technology) were in residence at NCGIA/UCSB during August 1991, and worked with Jeff Star on data conversion issues, as well as writing a proposal for follow-on work.

Initiative 13: User Interfaces for Geographic Information Systems (began June 1991). This initiative addresses human-computer interaction methods and related issues in the design and implementation of user interfaces for GIS and other geographical software. It is the first new initiative introduced since the NCGIA was awarded by NSF, and was introduced partly in response to the URISA research agenda, and partly as a natural outgrowth of the applied side of Initiative 2 ('Languages of Spatial Relations'). Specifically, cognitive and linguistic models dealing with geographic space are being formalized and further developed in order to provide a sound basis for the design and evaluation of user interfaces. The research initiative has as its broad goals: to investigate ways for people to interact with computers when solving problems concerning geographic space and spatial phenomena; to model some of the ways in which disciplinary background and training, problem domain, culture, natural language and individual differences influence such interaction; to establish criteria and methods for the design of user interfaces for geographic software; and to devise and test prototype interface development tools.

In order to gather opinions of a wide range of GIS users, panel discussions or workshops were held at three meetings during the spring of 1991. First, two panel sessions were held at the Association of American Geographers' meeting in Miami (April 14-17, 1991). These panels were in consecutive time slots. The first emphasized "User Needs", and included R. Aangeenbrug, W. Craig, G. Elmes, T. Nyerges, and A. Williams as panelists. The second panel, which included M. Armstrong, D. Mark, and M. McGranaghan, focused on "Possible Solutions". Next, a "Special Interest Group" (SIG) session, led by Werner Kuhn (Maine) and David Mark (Buffalo), was held at the ACM Computer Human Interaction meeting (CHI'91) in New Orleans (April-May 1991). About 50 people attended the SIG, and many signed an "interest list" and were placed on an electronic mailing list. Finally, a panel discussion was conducted at the ESRI User Conference (Palm Springs, late May 1991). This session, which was chaired by R. Aangeenbrug, and included M. Gould, J. Jackson, D. Lanter, and D. Mark, was very well attended, and stimulated further interest in and comments on the topic.

The Buffalo site hosted the specialist meeting June 22-26, 1991. Of the 41 official participants in the meeting, about three-quarters were from the GIS community, and one quarter from the Human-Computer Interaction (HCI) community. Also, 15 participants had attended at least one earlier NCGIA Specialist Meeting, and the remaining 26 were at their first such meeting. Finally, 12 participants were from the private and public sectors, and 29 were university-based researchers. Eight of the participants were graduate students, five from outside the NCGIA.

The Specialist Meeting began with a half day on the campus of SUNY at Buffalo. Following introductory remarks and background information, the participants spent about two hours in the Geographic Information and Analysis Laboratory (GIAL) viewing software demonstrations, mainly by participants. Then, they travelled by bus to Peek'n Peak, an all-seasons resort and conference center in Chataqua County, New York, about 90 miles from Buffalo, where the remainder of the meeting was held.

Participants were expected to produce position papers for circulation before the meeting (all but a small few complied), and to read all of the position papers before the meeting. Thus, we did not have any formal presentations by participants, but immediately began a cycle of periods with four or five 'break-out' groups, interspersed with 'break-out' reports and general discussions in the large group.

There was very little discussion of user interfaces at a 'surface' level (for example, icon design). Rather, the discussion concentrated on conceptual issues, and on needs for evaluation and testing. The needs for typologies of GIS tasks on the one hand, and users and use types on the other, was deemed to be of high priority. Other themes included:

- recognition that spatial concepts are critical to the design of user interfaces for GIS;
- the process of user interface design (as practiced in the HCI community) has many striking similarities to the process of GIS design, in which a potential adopter's needs and uses are identified and compared to existing or potential software systems;
- the issue of trade-offs between learnability on the one hand, and performance for experienced users on the other, is central;
- public access to information is primarily a user interface problem, combined with a legal problem; public access to computerized information is of almost no use if useable, natural user interfaces are not provided along with the data;
- experimental testing is a critical part of the research agenda; many researchers with little or no training in experimental psychology would benefit from a cook-book approach to testing needs, situations, and methods, similar to the charts of what statistical methods to use in the end-pieces of Blalock's *Social Statistics*;
- a specific issue of concern to the agencies and other large organizations is how to write product specifications for the user interfaces of systems, and how to determine whether the contractor or vendor has met those specifications.

The prioritized research agenda, a report on other discussions at the meeting, and the position papers, will be published as an NCGIA Technical Paper early in 1992.

A BITNET Listserver called UIGIS-L was established for discussion of these and other issues related to "User Interfaces for Geographic Information Systems"; by September 1991, UIGIS-L had about 100 subscribers.

Several graduate students have been directly involved in Initiative 13 research. At Buffalo, Michael D. Gould, who has been very active in publishing material under NCGIA Research Initiatives 2, 6, and 13, is completing his PhD on an Initiative 13 topic, and expects to defend his dissertation during 1992. In September 1991 he began working for ESRI-España in Madrid, Spain, and teaching part time at the Universidad de Alcala de Henares, Spain. His dissertation research uses protocol analysis to analyze the words used in geographic problem-solving by English-speakers and Spanish-speakers, and to compare subjects in Quito, Ecuador, with subjects in Buffalo, New York. Michael Mulligan, a US Defense Mapping Agency employee on advanced training at Buffalo during 1990-91, completed a Master's degree, including a research project entitled "User Interfaces: Some Issues for Larger Spatial Data Handling Organizations", in September 1991.

David Mark is working with Martin Helander (NCGIA-Buffalo research scientist from the Department of Civil Engineering) and Pawan Vora (one of Helander's graduate students) on an I-13 related proposal to be submitted to the Information Sciences Division of the NSF. There is discussion with CSIRO in Australia about a possible joint conference on User Interfaces. David Medyckyj-Scott, of the Department of Computing Studies at Loughborough, UK, has an I-13 related book in progress.

While the group in Maine concentrates on spatial reasoning aspects of user interfaces for GIS, researchers in Vienna working with Andrew Frank emphasize the communication and task modeling aspects. General research topics in Vienna are metaphors for spatial communication, spatial task analysis and multi-modal languages. Ongoing research concentrates on integrating metaphors into the (conceptual) design of interfaces; determining generic metaphors for GIS use; and visual abstraction mechanisms (pan and zoom). Ongoing collaboration between Maine and Vienna includes formalizing experiential spaces and implementing a user interface for the simplicial data model.

Initiative 14: GIS and Spatial Analysis (to begin February 1992). Consideration of the spatial dimension in statistical analysis creates a unique set of analytical problems; spatial analysis is not simply aspatial analysis performed on spatial data. This initiative will focus upon impediments to the accurate use of spatial analytic models in a GIS environment. Representative topics that fall within this initiative include spatial sampling methods, methods of spatial interpolation, the modifiable areal unit problem, spatial

autocorrelation, and the interface between the computation of spatial statistics and GIS data structures.

The plans for the I-14 Specialist Meeting are well under way. A hotel has been selected and reservations have been made for April 15-18 in San Diego, California (just prior to the AAG meeting, which begins April 19). Invitations have been sent out, and the final list of participants is almost established. Each invitee has been asked to provide a paper for the conference; a selected set of these papers will be presented on the first day of the specialist meeting, and another set will be published as a text.

Personnel from NCGIA to presented papers relating to I-14 at the Atlanta GIS/LIS in October 1991 in a session on GIS and Spatial Analysis; at the North American Regional Science Meetings in November 1991 in New Orleans; at the European RSA meetings in August 1991 in Lisbon; and at the Statistics Canada symposium on spatial data issues in Ottawa in November 1991. There are plans for presentations following the specialist meeting at the AAG meetings in San Diego, and the IGU meetings in Princeton in August 1992.

Research activities in the area of GIS and Spatial Analysis include Stewart Fotheringham's and Yuemin Ding's development of a statistical module that runs in ARC/INFO using AML; Fotheringham's and Ding's market analysis package that runs in ARC/INFO; a paper on the integration of GIS and Spatial Analysis authored by Fotheringham and Peter Rogerson; and an updating of a general spatial interaction modeling package, SIMODEL. Yuemin Ding is a PhD student in Geography at the University at Buffalo. At Santa Barbara, Luc Anselin's SpaceStat package for spatial statistical analysis will be distributed as a Center product beginning in April 1992.

Initiative 15: Multiple Roles for GIS in US Global Change Research (to begin 1993). The goal for this initiative is to improve our basic understanding of the multiple roles that GIS and GIA can play in the study of both the physical and human aspects of global environmental change. Our objective is to focus Center research on this integrating initiative, to take maximum advantage of the potential for generating external funding and to focus on a limited number of key priority research issues. We anticipate a major fundamental effort directed at exploring the use of GIS to improve the links between global physical process models and the human dimensions of global change. The United States Global Change Research Program (USGCRP) will make unprecedented demands for the acquisition, integration, analysis, manipulation and dissemination of large volumes of diverse and interdisciplinary data and information. Measurements acquired at regional and global scales must be merged with other often dissimilar data. Maps of many diverse phenomena based on information with a variety of spatial and temporal characteristics must be accomplished. Monitoring of both human and natural system must occur. Modeling aimed at improving our fundamental understanding of key physical and socio-economic processes will be required, as will our ability to translate information derived from these efforts into policy directed at the wise management of our global resource base.

Initiative 16: Law, Public Policy and Spatial Databases (to begin 1993). As evidenced by the rapidly growing computer law literature, society and the legal system are having great difficulty in dealing with the ramifications of technological advances. Nowhere is this more evident than with citizen reaction to spatial databases. The goal of this initiative is to advance scientific understanding of the law and public policy within spatial database environments in order to develop a body of legal and public policy knowledge which government, private industry, and other institutions will find valuable as they cope with the legal and social ramifications of GIS.

B. Education

With the completion of the NCGIA Core Curriculum in GIS in July 1990, educational activities at the Center have expanded to encompass a number of new areas.

Core Curriculum Distribution: The final version of the Core Curriculum was published in August 1990. By the end of 1991 approximately 900 copies had been distributed. Demand has been steady and a second and third printing have been necessary. A review of the distribution statistics provides some interesting details. Of the first 750 copies distributed, educational institutions had ordered 59%, commercial organizations 16%, government agencies 13% and individuals, libraries, research institutes, bookstores and publishers the remainder. Geography departments had accounted for the largest portion (36%) of the educational sector, but other departments had included geodesy, engineering, planning, environmental science, surveying, geology, forestry and natural resources, each with between 11% and 3%. The Curriculum had been sent to 49 countries, with US addresses having received the majority of the copies (51%). Canada was in second place with 9%, followed by the UK (7%), Australia (4%), Netherlands (4%) and Germany (3%). In addition to the national distribution program, a number of Core Curriculum purchasers are working independently on partial translations of the materials. We are aware of translations being prepared in Japanese, Czech, Chinese, Spanish and Korean.

Electronic Network for Curriculum Users: Registered users of the Core Curriculum who have electronic mail addresses received notice of the newly established Core Curriculum Users Discussion List which allows each member to broadcast requests, hints or comments to all other members of the list through the computer facilities of the NCGIA at Santa Barbara. This medium provides a useful forum for discussion of the Curriculum.

Volume 4 - Laboratory Materials: The first edition of the Volume 4 project was completed in August 1991 and published as an NCGIA Technical Report. Volume 4 is a compendium of information pertaining to GIS laboratory materials, including exercises developed by the NCGIA, exercises produced by vendors and at educational institutions worldwide, appropriate and accessible datasets and educational software. Its intent is to provide a catalog of information useful to instructors of GIS laboratory courses. Each entry in the catalog is indexed and cross-referenced by subject and application type, hardware and software requirements, geographical location, corresponding Core Curriculum units, etc. The catalog items are available either directly from the NCGIA or from other sources as indicated. The compendium will likely be updated every two years.

Laboratory Facility Study: A primary concern of GIS instructors is that of providing a laboratory facility for their students. To assist in this task, the center initiated a Laboratory Facility Study, with additional support from the Association of American Geographers. The final report was published in September 1991 and contains carefully researched case studies of the process followed by six very different institutions as they fought for and obtained their GIS labs. The report includes descriptions of the procedures followed, the supporting documents produced, budgets proposed and realized, hardware and software configurations and laboratory management schemes. The case study sites were selected in May, 1991. During the summer, each selected institution gathered information which was compiled and edited into a comprehensive technical report by the Center.

High School GIS: NCGIA has recently begun to assess the potential for GIS in secondary school education. We feel there are two distinct foci for this effort, one in the provision of basic training in GIS, and the other in the use of GIS as an educational tool. The center will continue to explore these possibilities in the coming year. A proposal for funding has been submitted to the Instructional Materials Development program at NSF.

International Activities: As invited speakers at several international conferences in the past year, NCGIA representatives have had the opportunity to discuss issues related to the use of the Core Curriculum in countries outside North America. Two international initiatives have emerged from these discussions. First, we have received a number of inquiries regarding distribution of the Curriculum in countries where translation may be necessary or where US currency for purchasing several copies is difficult to obtain. In response to this, we have developed a policy which allows interested parties in these countries to apply for the right to become national distribution representatives. If the application is approved, the individual receives permission to reproduce the Curriculum and distribute it within his or her own country at a price representing only the cost of this service. Such arrangements free us of the responsibility to locate international aid to assist these institutions and provide us with local contacts. Such national distribution sites have been established to date in China, Czechoslovakia, Estonia, Hungary, Japan, Korea, Morocco, Spain and Yugoslavia.

Second, we have initiated discussions with several European organizations concerning the development of a European or, possibly, a fully international version of the Curriculum. Such a document is likely to take the form of a supplement structured around the 75 original units and would include applications and references from many different countries and provide notes on aspects of GIS that vary from region to region. If the project is approved by the international sponsoring agencies, we hope that it can be completed within a year.

Publications: A paper describing the initial development of the Core Curriculum has appeared in the *Journal of Geography in Higher Education*, and a second describing the testing phase has been accepted. In addition both papers have been reprinted in a special issue of *Cartographica* on GIS education. A paper on the role of the curriculum and GIS in undergraduate education in geography has been accepted by *The Professional Geographer*.

Conferences: One consequence of the development of the Core Curriculum has been an increasingly focused debate on the nature of GIS education, as distinct from GIS training, and its relationship to established disciplines. Presentations on NCGIA education activities have been made at conferences on GIS in Higher Education held at Ohio State University in 1989 and 1990, and at the University of South Florida in 1991.

C. Outreach

1. General

The circulation of the Center newsletter *Update* is now approximately 2,500, including 500 overseas addresses. The newsletter is published approximately every nine months, the latest issue appearing in June 1991. Overview presentations on the work of the Center continue to be made at conferences and stories on the Center appear in magazines, newspapers, and journals, including *Professional Surveyor*, *Photogrammetric Engineering and Remote Sensing*, *Geo Info Systems*, *International Journal of Geographical Information Systems*, and the American Geographical Society *Newsletter*. Many Center researchers contributed chapters to the recently published 2-volume set *Geographical Information Systems: Principles and Applications*, edited by D.J. Maguire, M.F. Goodchild and D.W. Rhind (Longman Scientific and Technical, 1991).

At the present time there are 58 papers in the Technical Paper series and six other miscellaneous publications, and a total of 346 papers were listed in the NSF renewal proposal document. Requests for publications average about 40 per week, in addition to the Core Curriculum.

GIS and the Social Sciences, Santa Barbara (March 22-24, 1991). NCGIA-Buffalo and NCGIA-Santa Barbara sponsored a conference in Santa Barbara, "GIS in the Social Sciences", coordinated primarily by the Buffalo site. Forty scholars from human geography, political science, sociology, history, anthropology, and economics met to discuss applications of GIS and related methodologies in their disciplines. Approximately 20 papers were presented. The meeting provided an opportunity to learn how GIS can be helpful in social science research, and about the problems that GIS is currently not helping to solve in these areas. There was general agreement among the participants that the conference was a success, and that future meetings should be arranged. There was considerable interest in engaging social scientists in ongoing and future NCGIA research. In addition to this effort, the Center is participating in a book on GIS and the Social Sciences to be edited by Leonard Hochberg (Stanford) and published by Blackwell. Chapters on GIS and spatial statistics are being contributed by Goodchild and Anselin.

Canadian Cartographic Association Annual Meeting (June 1-3, 1991). Barbara Battenfield, Connie Holoman, and David Mark coordinated a one-day program for this meeting, which convened at Brock University (St. Catharines, Ontario) June 1-2, and at the NCGIA in Buffalo June 3. Approximately 85 people participated in the Buffalo program, 60 of whom came from the meeting at Brock. NCGIA students and faculty presented software and hardware demonstrations in the morning session, and participated in paper presentations in the afternoon.

Workshop on Sacred Geography and Computer Modeling in the Pacific Rim Area (Santa Barbara, July 1-3, 1991). This three day conference was the culmination of a joint project between NCGIA and the Department of Religious Studies at UCSB. Space has meaning to many cultures, and those around the Pacific Rim give a great variety of meanings to the spaces they occupy. The conference brought a small group of 16 participants together to discuss the use of remote sensing and GIS in the investigation of sacred spaces, as such places have been articulated by peoples in Japan, China and California. The project was sponsored by NCGIA and the UC Pacific Rim Research Program.

Symposium on the Design and Implementation of Large Spatial Databases (SSD '91) (Zurich, August 1991). Following the success of the first symposium in Santa Barbara in July 1989, the precursor meeting to the Initiative 5 specialist meeting, a second meeting in the SSD series was organized in Zurich in August 1991. Frank, Goodchild, Egenhofer and Smith were on the program committee.

First International Conference/Workshop on Integrating GIS and Environmental Modeling (Boulder, CO, September 15-19, 1991). Geographic Information Systems are thought to have significant potential for analysis and modeling in those sciences dealing with spatially distributed phenomena. Modeling offers the means to extend understanding of the past and present, and to anticipate future events, by predicting the behavior of environmental systems under changing circumstances. By using a common geographical frame of reference, GIS technology offers the means to integrate and interpret spatial data from different disciplines and sources. This capability is increasingly important for work which is inherently multidisciplinary, particularly environmental science, natural resources management, development planning, and the study of pressing ecological issues such as global environmental change. This conference/workshop emphasized integrating GIS with modeling in all of these areas. Over 600 participants registered for the conference, which featured plenary presentations of overviews and case studies in each area of modeling; tutorials in GIS, spatial statistics and risk; and working group discussions. Invited presentations will form the basis of an edited reference volume to be published by Oxford University Press in 1992. The meeting was sponsored jointly by NCGIA, IBM Corp and a group of federal

agencies including EPA, NASA, USGS, DOE, the Army Corps of Engineers and the US Fish and Wildlife Service.

3D in Remote Sensing and GIS: Systems and Applications (Munich, September 16-22, 1991). In September 1991 the Center co-sponsored this conference on 3D techniques in GIS with ISPRS Commissions II and VII.

Computer Modeling of Groundwater Flow and Contaminant Transport (Santa Barbara, December 6, 1991). This conference on the use of GIS and other technologies in modeling groundwater flow was co-sponsored by NCGIA Santa Barbara, the Hydrology Laboratory of the UCSB Department of Geography, and the Vadose Zone Laboratory of the UCSB Institute of Crustal Studies.

The Anthropology of Human Behavior through Geographic Information and Analysis (Santa Barbara, February 1-2, 1992). Major advances in the use of geographical information systems have been made in both anthropology and archaeology. Nevertheless, there have been relatively few published discussions of how GIS can be used to approach and solve complex problems in substantive research. Although discussions of the technical aspects of GIS will continue to be of importance, an alternative means of popularizing GIS in anthropology and archaeology is to demonstrate the role of GIS in the context of research. This conference seeks to bring together anthropological users of GIS to describe research that was either too difficult or impossible using any other tools. Some 25 paper presentations are planned over two days. The meeting will be sponsored by NCGIA, the UCSB Social Science Computing Facility and the UCSB Department of Anthropology.

At the Maine site, Max Egenhofer is in the process of forming a Special Interest Group on Geographic Information Systems, tentatively called SIGGIS, within the Association of Computing Machinery (ACM). This interest group will cooperate with the AAG Specialty Group on GIS and will provide a focal point for computer scientists interested in GIS.

Also at the University of Maine, Gary Jeffress, former graduate student, Raymond Hintz, Associate Professor of Surveying Engineering, and Harlan Onsrud, have been awarded the R.D. Steele Prize for 1990 by the Council of The Institution of Surveyors, Australia, Inc., for their paper "An Automated Measurement Management System: A Useful Tool for Surveyors and Digital Cadastral Data Base Managers," which was published in the March 1990 issue of *The Australian Surveyor*.

NCGIA-Maine has produced a color brochure entitled "Geographic Information and Your Future: Careers for a Fragile Planet", which will be distributed widely throughout the United States to attract high school students to careers in geographic information studies.

Several cooperative agreements have been signed between NCGIA sites and other cognate laboratories and research groups in the past year. In June, an agreement was signed between the Buffalo site and the Laboratory of Resources and Environment Information System (LREIS), Chinese Academy of Sciences, for scholarly exchange and collaboration.

2. GIS-L

GIS-L is a LISTSERV electronic mail distribution list for the dissemination of information about geographic information systems, and the discussion of issues. It was initiated on June 18th, 1988 by Ezra Zubrow of the NCGIA and Department of Anthropology, State University of New York at Buffalo. GIS-L is a public list, which means that anyone with electronic mail ('email') access to BITNET, Internet, or other connected networks may subscribe to GIS-L and subsequently receive posted materials. Also, GIS-L is an unmoderated list, which means that anyone on email can post (distribute) items for distribution to all GIS-L subscribers. GIS-L is also available as a Usenet news group named bit.listserv.gis-l. The purpose of GIS-L is to promote discussion and dissemination of information related to Geographic Information Systems (GIS). Currently, Zubrow and David Mark (NCGIA and Geography, SUNY Buffalo) are co-owners of GIS-L and maintain the list, with help from James Gerland of the SUNY Buffalo Academic Computing Center.

Membership. In the earlier days of GIS-L, no records of subscriptions, 'sign offs', or numbers of members were kept. However, since April 1990, those figures have been monitored. Some subscriber totals between April 1990 and the present are:

April	18	1990	238
June	8	1990	252
Nov	2	1990	339
Nov	20	1990	368

Dec	17	1990	371
Jan	1	1991	363
Jan	20	1991	386
Feb	16	1991	425
June	17	1991	545
Sep	29	1991	624

Note that GIS-L membership has about doubled in the last year. The growth rate in the last period had been somewhat slower (0.76 net additions per day) than in the previous (0.99 net additions per day), and if the growth pattern continues, the equilibrium membership would be around 1,000.

Who are the GIS-L subscribers? A tabulation of the affiliations of subscribers as of September 29, 1991 revealed the following distribution:

US Academic sector	291	46.6%
US Private sector	41	6.7%
US Governmental sector	26	4.2%
Total US subscribers	358	57.5%
Foreign subscribers	266	42.5%
Total subscribers	624	100.0%

Table 1: Subscribers by Country of Residence; February, June & September 1991

Country		Feb 18	Jun 17	Sept 29 Total	BITNET/ EARN	Internet
United States		246	320	358	191	167
	(Academic)	205	254	291	177	114
	(Commercial)	28	51	41	2	39
	(Government)	13	15	26	12	14
Canada		57	64	73	30	43
UK		26	40	38	-	38
Australia		14	20	31	-	31
Brazil		2	6	13	10	3
Netherlands		7	10	11	5	6
Finland		11	12	10	9	1
Germany		3	8	8	4	4
Austria		7	8	7	4	3
New Zealand		4	5	7	-	7
Taiwan		3	5	6	5	1
Turkey		2	5	6	6	-
Italy		4	2	6	2	4
Spain		3	5	5	5	-

Norway	1	4	5	1	4
Denmark	5	3	5	-	5
France	6	4	4	3	1
Saudi Arabia	2	2	4	4	-
Ireland	5	4	3	2	1
Chile	2	2	3	3	-
Japan	3	2	2	2	-
Mexico	2	2	2	2	-
Switzerland	2	2	2	2	-
Czechoslovakia	-	1	2	2	-
Sweden	1	1	2	-	2
Hong Kong	-	2	1	1	-
Israel	5	2	1	1	-
Greece	1	1	1	1	-
Poland	1	-	1	1	-
Tunisia	-	-	1	1	-
Belgium	-	-	1	1	-
Zaire	-	-	1	-	1

GIS-L subscribers are from 32 countries. Outside the United States, 116 subscribers are from Europe, 73 from Canada, 38 from Australia and New Zealand, 19 from Asia, 18 from Latin America, and (since June 1991) 2 from Africa. Table 1 presents subscriber totals by country for three dates in 1991. For September 1991 the figures are separated according to whether the subscription is through BITNET/EARN (302 subscriptions) or Internet (322 subscriptions).

In fact, these figures greatly underestimate the impact of GIS-L on the dissemination of information about GIS. First, at least 23 of the ‘subscribers’ to GIS-L (12 in the United States, 11 elsewhere) actually are local news redistribution lists, rather than individuals. It is not easy to find out how many people receive GIS-L indirectly this way. However, a good example is the GIS-L list at ESRI, the California-based firm that develops and markets ARC/INFO, which includes 33 subscribers; this reorganization, which happened in July 1991, is the main reason for the apparent drop in US-based private-sector subscribers during the summer of 1991. Secondly, as noted above, GIS-L is ‘re-broadcast’ as a Usenet news group named bit.listserv.gis-l (Usenet is a news distribution system available on most UNIX systems and some others). Unlike LISTSERV, which send an electronic mail message directly to each subscriber, Usenet allows its subscribers to ‘read’ items of interest from files held outside the user’s account, to scan unread mail by topic, to screen out specific topics of non-interest, etc. The domain that redistributes BITNET list server material (bit.listserv._____) is not available at all Usenet sites, but GIS-L reaches many people this way. Finally, many GIS-L items are forwarded by subscribers to non-subscribers, based on interests and topics, and are sometimes re-posted to other lists. It seems reasonable to suspect that a typical GIS-L posting now reaches well over a thousand readers.

Table 2: Postings on GIS-L to Saturday, 18 June 1988 (1196 days)

Sender’s name	Number of postings	Pct
Duane F. Marble	346	10.2
Darius Bartlett	145	4.3
David Mark	124	3.7
Dan Yurman	101	3.0
David H. Douglas	83	2.5
Michael Gould	57	1.7
Melcir Erskine-Richmond	51	1.5
Lee De Cola	49	1.4
Ezra Zubrow	48	1.4
George L. Benwell	40	1.2
Ted Samsel	37	1.1

Top 12 posters (over 1%)	1,081	32.0 %
Total (mail):	3,380	100.0 %

Postings. Statistics obtained from the LISTSERV software on September 29, 1991 (after 1,196 days, of operation) reveal that a grand total of 3,380 items had been posted to GIS-L, yielding a mean rate of about 2.8 items per day (Table 2). However, the flow of messages has by no means been uniform, with fairly long quiet periods punctuated by bursts of activity. Over 500 people or computer accounts have posted to GIS-L since its inception. However, the 11 individuals who have posted 34 items or more (over 1%) have together posted 1,081 items (32% of all postings). The group of 'frequent posters' is quite heterogeneous. Three are from US government agencies (Yurman, De Cola, Samsel), two are from Canada (Douglas, Erskine-Richmond), one from Ireland (Bartlett), one from New Zealand (Benwell), and the remaining four are US-based academics.

Including the above, about a quarter of the postings so far have been from foreign sites; since about 42% of subscribers on 29 September 1991 were from non-USA sites (see above), GIS-L is producing a net flow of information about GIS-related topics from the United States to the rest of the world. About ten percent of the postings originated from the three NCGIA sites, and some of these were related to the maintenance of the list. Thus GIS-L is an outlet and forum for the entire GIS community, and not simply a method of information dissemination by the Center.

3. Technical Papers published in 1991

The following titles were added to the Technical Papers series in 1991:

91-1: Fractal Geometry and Spatial Phenomena by Mark MacLennan, A. Stewart Fotheringham and Mike Batty, SUNY-Buffalo; Paul Longley, U. Wales, bibliography prepared in conjunction with Initiatives 1 and 3 as an aid to research.

91-2: A Conceptual Framework for Integrated Metadata Management in Very Large Spatial Databases, by Nehal Trivedi and Terence R. Smith, UCSB, presents a conceptual framework for integrated metadata management in large spatial databases.

91-3: A Cartographic Animation of Average Yearly Surface Temperatures for the 48 Contiguous United States: 1897-1986, by Christopher Weber, SUNY-Buffalo, describes a variable cartographic animation process employing hardware and software.

91-4: Temporal Relations in Geographic Information Systems: A Workshop at the University of Maine, Orono, October 12-13, 1990 by Renato Barrera, Andrew Frank and Khaled Al-Taha, U. Maine, proposes a model of time useful in analysis of temporal accuracy of geographic information.

91-5: The Integration of Spatial Analysis and GIS: The Development of the STATCAS Module for ARC/INFO by Y. Ding and A. Stewart Fotheringham, SUNY-Buffalo, describes the STATCAS package that runs within the operating environment of a GIS.

91-6: User-Centered Graphical User Interface Design for GIS by David Lanter and Rupert Essinger, UCSB, discusses how traditional user interface design focuses on the best way to represent the software functionally rather than on how to meet the expectations of the user.

91-8: Spatial Data Representation and Basic Operations for a Triangular Hierarchical Data Structure, by Michael Goodchild, Yang Shiren, and Geoffrey Dutton, UCSB, describes the recursive subdivision of an octahedron and the conversion algorithms to and from latitude/longitude.

91-9: Spatial Decision Support Systems: A Bibliography, by Michael Gould and Paul J. Densham, SUNY-Buffalo, bibliography compiled from various sources including journal indices, book indices, and databases.

91-10: Designing and Implementing Strategies for Solving Large Location-Allocation Problems with Heuristic Methods by Paul Densham SUNY-Buffalo, and Gerard Rushton, SDSU, describes the implementation of the best known heuristic algorithms used to solve large problems in times that are realistic in a microcomputer-based, interactive decision making environment.

- 91-11: Connecting ARC/INFO and SNACTor: Project Report, by Stuart C. Shapiro, Hans Chalupsky, and Hsueh-cheng Chou, SUNY-Buffalo, describes an interface between ARC/Info and SNePS, the Semantic Network Processing System, a knowledge representation and reasoning system.
- 91-12: GIS Laboratory Exercises: Volume 1, edited by Rustin F. Dodson, UCSB, exercises designed to illustrate and reinforce principles presented in Volume I: Introduction to GIS of the NCGIA Core Curriculum; includes two diskettes.
- 91-13: The Performance of Tests for Spatial Dependence in a Linear Regression, by Luc Anselin and Serge Rey, UCSB, compares the properties of Moran's I and Lagrange multiplier tests for spatial dependence.
- 91-14: GIS Laboratory Exercises: Volume 2 Technical Issues, by Howard Veregin, exercises designed to illustrate and reinforce principles presented in Volume II: Technical issues in GIS of the NCGIA Core Curriculum; includes one diskette.
- 91-15: An Annotated Bibliography on Human Computer Interaction for GIS, compiled by the students in Course SVE 698, U. Maine, bibliography collected by the instructor and students during a course on human computer interfaces for GIS.
- 91-16: Initiative 12: Integration of Remote Sensing and Geographic Information Systems, Report of the Specialist Meeting, summarizes the planning meetings and preliminary work that led to the first Specialist Meeting for Initiative 12.
- 91-17: Multiple Topological Representations, by Bud P. Bruegger and Werner Kuhn, U. Maine, proposes an approach to support multiple levels of abstraction in a GIS through multiple topological representations (MTR).
- 91-18: Visual Interfaces to Geometry, by Werner Kuhn and Max J. Egenhofer, U. Maine, presents the results of a two-day workshop on "Visual Interfaces to Geometry, conducted at ACM's CHI'90 Conference on Human Factors in Computing Systems.
- 91-19: The Use of a Geographic Information System for Second-Order Analysis of Spatial Point Patterns, by Mark J. MacLennan, SUNY-Buffalo, describes a computer program for GRASS which implements second-order neighborhood analysis.
- 91-20: The NCGIA Guide to Laboratory Materials - 1991, edited by Rustin F. Dodson, Karen K. Kemp, and Stephen D. Palladino, UCSB, compendium describing sources of student exercises, appropriate digital data sets, and miscellaneous materials.
- 91-21: GIS Teaching Facilities: Six Case Studies on the Acquisition and Management of Laboratories, edited by Stephen D. Paladino and Karen K. Kemp, UCSB, includes six case studies reviewing the acquisition and management of computer labs established primarily for teaching GIS.
- 91-22: Bibliography on Animation of Spatial Data: A Guide to Literature, Video and Movie Media, by Barbara P. Battenfield, Christopher R. Weber, Mark MacLennan, and John D. Elliott, SUNY-Buffalo, a collection of sources collected as part of the research efforts for Initiatives 7 and 10.
- 91-23: The Use of Vegetation Maps and Geographic Information Systems for Assessing Conifer Land in California, by Michael F. Goodchild, Frank W. Davis, and David M. Stoms, UCSB, summarizes the research into the nature and sources of error in medium to small-scale vegetation maps used for state-wide forestry conservation planning.
- 91-24: German GIS/LIS Standards by Werner Kuhn, U. Maine, investigates cadastral and topographical information management in Germany, 1990.

D. Management

Board of Directors. The Board of Directors oversees the reporting of Center activities to NSF, and acts in an advisory role to the other Center committees. Several changes occurred in the membership of the Board of Directors in Year 3. The Board welcomed Dr. Roberta Lenczowski (Defense Mapping Agency), Dr. Ronald Abler (Association of American Geographers) and Dr. Lawrence F. Ayers, Jr. (Intergraph Corp). Meetings were held in Santa Barbara (December 1990) and Buffalo (June 1991) and at the end of November 1991 were:

Joel Morrison (US Geological Survey), Chair
 Ronald F. Abler (Association of American Geographers)
 Lawrence F. Ayers, Jr. (Intergraph Corp)
 John R. Borchert (University of Minnesota) (Member, National Academy of Sciences)
 John Bossler (Ohio State University)
 Jack Dangermond (ESRI)
 Herbert Freeman (Rutgers University)
 John B. Garver, Jr. (National Geographic Society)
 Roberta Lenczowski (Defense Mapping Agency)
 Patrick E. Mantey (University of California, Santa Cruz)
 D. David Moyer (University of Wisconsin-Madison and URISA)
 John R. Rosati (TRW)
 Gerard Rushton (University of Iowa)
 G. William Skinner (University of California-Davis) (Member, National Academy of Sciences)
 Shelby Tilford (NASA)

The period of service of five members - Borchert, Bossler, Dangermond, Rosati and Tilford - was due to end after the December, 1991 Board meeting.

Executive Committee. The Executive Committee is made up of the Director and Associate Directors, and the Chair of the Scientific Policy Committee. The Director is responsible for overall management of the Center, and the Associate Directors for management of operations at each site. Michael F. Goodchild became Director in July 1991; until then the Center had been headed by two Co-Directors. New Associate Directors were appointed at all three sites at various times during year 3: at Santa Barbara Luc Anselin replaced Terence Smith; at Buffalo Michael Batty replaced Ross MacKinnon; and at Maine David Tyler replaced Andrew Frank. At the end of November 1991 the membership of the Executive Committee was: Goodchild, Director; Anselin (Santa Barbara), Batty (Buffalo), and Tyler (Maine), Associate Directors; and David Mark (Buffalo), Chair of the Scientific Policy Committee.

Scientific Policy Committee. During the year from December 1, 1990 to November 30, 1991, the Scientific Policy Committee (SPC) held formal meetings in Santa Barbara in December 1990, and in Buffalo in June 1991. Some SPC members also met informally at the AutoCarto meeting in Baltimore in April 1991, and at the GIS/LIS meeting in Atlanta in early November 1991, and all were present at the strategic planning retreat in San Diego in February 1991. David Mark (Buffalo) served as Chair of the SPC throughout the period. Michael Batty replaced Ross MacKinnon as one of three Buffalo representatives; and David Tyler was added from Maine, the Maine complement being raised permanently to three. From Santa Barbara, Luc Anselin was added and Terence Smith's tenure was extended temporarily to provide continuity.

Three new initiatives were approved by the SPC during the year: 14 (GIS and Spatial Analysis), 15 (Multiple Roles for GIS in US Global Change Research) and 16 (Law, Public Policy and Spatial Databases). Invitations to submit proposals and suggestions for new initiatives were widely circulated to the research community through the newsletter and the GIS-L electronic list server, and the responses were discussed at the December 1991 Board of Directors and SPC meetings. Because of interest expressed by various Board members, Joel Morrison was invited to attend the June 1991 SPC meeting, and other Board members will be attending future SPC meetings.

Personnel changes. At Maine, Max Egenhofer was appointed Assistant Professor in the Department of Surveying Engineering, effective September 1, 1991. Werner Kuhn completed his Post-Doctoral appointment with the NCGIA and has taken a position as Research Associate at the Department of Geo Information at The Technical University of Vienna. Matt McGranaghan completed his appointment as Visiting Professor with the NCGIA at the end of June and has returned to his position at the University of Hawaii. Andrew Frank resigned his position as tenured Professor in Surveying Engineering at the University of Maine, but he will continue to spend up to 50% of his time on NCGIA research as a Research Professor. Manfred Ehlers resigned his position as Associate Professor of Surveying Engineering at the University of Maine and has been appointed Professor of Remote Sensing, ISPA, Vechta University,

Germany. Renato Barrera completed his appointment with the NCGIA at the end of June, and has joined Intergraph Corporation. William Mackaness has been appointed to a two-year term as a Research Associate with the NCGIA, effective October 7, 1991.

At Buffalo, Michael Batty joined the NCGIA on January 1, 1991, as the new Director of the Buffalo site and as Associate Director for the National Center. Batty came to the Buffalo site from the University of Wales at Cardiff, where he had held a Chair of City and Regional Planning since 1979. Batty replaced Ross MacKinnon, who stepped down from the position of Director of the Buffalo site effective December 31, 1990, after serving in that role since the Center's inception. MacKinnon remains an active member of the Center.

At Santa Barbara, Judith Parker joined the Center as Office Manager in March 1991, and oversees a staff of four, including the Publications Office. Dr. C.K. Chow continued his appointment as IBM representative, in connection with the UCSB/IBM joint study agreement. Visiting scholars making extended stays at Santa Barbara in year 3 included Manfred Ehlers (ITC, Netherlands), Yee Leung (Chinese University of Hong Kong), and Nicholas Faust (Georgia Tech).

Space. At Maine, the NCGIA and the Department of Surveying Engineering moved into their new quarters in the Llewellyn N. Edwards Wing of Boardman Hall in May 1991. This purpose-built 3 story addition to Boardman Hall meets the office needs of faculty, research personnel, administrative staff, and graduate students. In addition, the group has gained spacious quarters for the GIS and photogrammetry laboratories. There is a large conference/library room and a seminar room, both of which will be used regularly for NCGIA/Department functions. Additional, at present unfinished, space on the second floor is scheduled to be completed in mid-January 1992, offering even more office and laboratory space.

3. EXTRAMURAL SUPPORT

A. Grants and Contracts Awarded as of 11/30/91

CALTRANS: "GIS Long Range Development Plan"; \$13,372. PI: Goodchild. November 1990 - June 1992.

CALIFORNIA DEPARTMENT OF FORESTRY AND FIRE PROTECTION: "Forestland Mapping Accuracy Assessment"; \$68,000. PI: Goodchild. June 1991 - June 1992.

CANADIAN EMBASSY, WASHINGTON, DC: "Money and Votes: Campaign Expenditure and Electoral Outcomes in Canada, 1980-1988"; \$4,500. PI: Munroe Eagles. December 1990 - February 1992.

CSRS/US DEPARTMENT OF AGRICULTURE: "On-Farm Information System for Groundwater Protection"; \$23,688. co-PI: Tyler. July 1991 - June 1994.

DEFENSE MAPPING AGENCY: "I-12 - Remote Sensing and GIS"; \$26,736. PIs: Estes, Davis, Star. July 1991 - April 1992.

EG&G ENERGY MEASUREMENTS: "Improved Integration of Remote Sensing Imagery with GIS"; \$47,084. PI: Lanter. August 1991 - February 1993.

ENVIRONMENTAL PROTECTION AGENCY: "Remote Sensing and GIS Technology Demonstration and Basic Research Cooperative Agreement"; \$182,500. PI: Estes. July 1990 - June 1992.

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE: Award for Barbara Bittenfield to attend an ESRI workshop, "Expert Systems in GIS"; \$1000. July 1991.

INTERGRAPH CORPORATION: Max Egenhofer (PI) and Andrew Frank (Co-PI) have been awarded a 3-year research contract (1992-1994) to continue work on reasoning about spatial relations. \$157,625.

NASA: "I-12 - Remote Sensing and GIS"; \$49,501. PIs: Estes, Davis, Star. July 1991 - April 1992.

NATIONAL FISH AND WILDLIFE FOUNDATION: "GIS Analysis of Biodiversity in California"; \$135,000. PI: Davis. July 1990 - June 1992.

NATIONAL INSTITUTE FOR GLOBAL ENVIRONMENTAL CHANGE (US DEPARTMENT OF ENERGY): "Climate and North American Plant Formations: Associations Between the Water Balance and Satellite-Derived Vegetation Patterns"; \$85,000. Co-PIs: D. E. Jelinski (\$73,749) and A.M. Carleton (University of Indiana). July 1991 - July 1992.

NATIONAL SCIENCE FOUNDATION: "Spatial Properties of Configurational Knowledge"; \$75,735. PI: Golledge. March 1991 - August 1992.

NATIONAL SCIENCE FOUNDATION: "Improving Human-Computer Interaction in Locational Decision-Making"; \$99,810. PIs: Paul Densham (50%) and M. P. Armstrong, University of Iowa, (50%). June 1991 - December 1992.

NATIONAL SCIENCE FOUNDATION: "Toward a System that Supports Conceptual Modeling in Data Intensive Scientific Investigations"; \$610,808. PIs: Smith, Dozier and others. November, 1991 - October, 1994.

NATIONAL SCIENCE FOUNDATION: "Collaborative Research on the Spatial Analysis of International Conflict and Cooperation"; \$68,729. PI: Luc Anselin. February 1990 - January 1992.

NORTH ATLANTIC TREATY ORGANIZATION: Harlan Onsrud and Ian Masser (University of Sheffield) were awarded one million Belgium francs to conduct an Advanced Research Workshop on "Modeling Diffusion and Use of Geographic Information Technologies".

NORWEGIAN MARSHALL FUND: NOK 18,000. Funding to support research visit to Norway to use super computer technology with excavation results from a Norwegian archaeological site. PI: Ezra Zubrow. August 1991.

US DEPARTMENT OF AGRICULTURE: "Analytical and Graphic Support Systems for Landscape Analysis Related to Forest Plan Implementation and Update"; \$42,619. PIs: Church, Lanter. March 1991 - September 1992.

US ENVIRONMENTAL PROTECTION AGENCY (ERL-Duluth): "Development of a Geographically-Based Ecological Modeling Framework for Exposure-Effects Analysis of Contaminants in the Lower Great Lakes"; \$1,643,005. Co-PIs: J.V. DePinto, J. Atkinson, H. Calkins (10%), P.J. Densham (10%), R.R. Rumer, and S. Taylor.

US FOREST SERVICE: "Integrated Information Management Program: Performance Validation Project"; \$10,000. PI: Hugh Calkins. May - August 1991.

US GEOLOGICAL SURVEY: "I-12 - Remote Sensing and GIS"; \$31,072. PIs: Estes/Davis/Star. July 1991 - April 1992.

UNIVERSITY TRANSPORTATION RESEARCH CENTER (Region II, CUNY Institute of Transportation Systems): "GIS Technology for Integrated Management of Transportation Systems"; \$49,994. PI: Satish Mohan, Department of Civil Engineering; Co-PI: Hugh Calkins.

First International Conference/Workshop on Integrating GIS and Environmental Modeling: IBM Corp and 10 agencies (EPA, USGS, ORNL, Army Corps of Engineers, US Fish and Wildlife Service, US Forest Service, NOAA, Minerals Management Service, NASA and National Institutes for Global Environmental Change) contributed a total of \$90,000 to the support of this conference organized by NCGIA.

B. Equipment and Software Grants Awarded as of 11/30/91

CALIPER CORPORATION: Grant of two copies of GisPlus Software for research and teaching, retail value: \$20,000. Paul Densham.

COREL SYSTEMS: Coreldraw! software grant (\$1530 value) to David Lanter for installation on RS/6000 workstations for instruction.

DIGITAL EQUIPMENT CORPORATION: Hardware obtained under a grant of \$500,000 to the UCSB Map and Imagery Laboratory was dedicated in February 1991.

ERDAS, INC.: Site license for image processing software to teach a remote sensing course in the Spring Semester 1991.

NATIONAL SCIENCE FOUNDATION: David Tyler and Kate Beard (Co-PI's) have been awarded an NSF ILI grant for a GIS - Image Processing Laboratory; \$28,331, with a \$28,331 match from the University of Maine.

SOIL CONSERVATION SERVICE: EPIC software (Erosion Prediction Inventory Calibration—a numeric model for water quality) for the DOS platform. Barbara Battenfield.

UNIVERSITY AT BUFFALO: \$20,000 in computing equipment funding. Michael Batty.

C. Equipment and Software Acquisitions

For staff and faculty offices at Buffalo:

Three Sun IPC workstations, one with a 1.3 gb storage module
 Macintosh IICI with color monitor
 Macintosh IIfx running A/UX with color monitor
 Toshiba 1000LE laptop "notebook" portable computer
 Canon BJ-10e portable bubble-jet printer for use with the Toshiba
 GRASS (Geographical Resources Analysis Support System) for Sun platform
 MacGRASS for Macintosh platform

For the Geographic Information and Analysis Lab (GIAL) at Buffalo:

Upgrade for the remaining Sun 3/60 to a SparcStation 2
 3 QMS laser printers, including network interfaces for AppleShare and Novell printing capabilities
 Four TransCad licenses for DOS platforms
 Apple CD-ROM player
 8mm tape backup unit for the Novell server
 CLIPS, an expert system shell builder

Software upgrades for Systat, Adobe Illustrator, and Turbo Pascal

For the GIAL "dry darkroom" at Buffalo:

Hewlett Packard 386 PC with Super VGA display
 Macintosh IIfx with 24 bit color display
 Polaroid Bravo slide maker with transparency adapter and Mac and DOS interface software

For the NCGIA office complex at Buffalo:

Polaroid Bravo zoom overhead projector
 Proxima VersaColor LCD projector with Mac and DOS interfaces
 Projection screens
 Panafax plain paper fax machine

For instruction at Buffalo:

20 copies each of Sim City Supreme and Sim Earth for UB's new undergraduate World Civilization curriculum, one section of which is being taught from a geographical perspective.

PCs & Workstations at Maine:

Gateway 2000 386 personal computer
 Microsmart 386/SX 20 MHZ system with super VGA personal computer
 Mac II si (5)
 Gateway 2000 386 personal computers (5) with 80387 Math Coprocessors (5)
 Gateway 2000 486 personal computer

Communication Devices at Maine:

MMAC III network hardware
 Ethernet Transceivers (3)
 2 Ethernet PC cards
 Mac Asante Ethernet cards (5)
 PC Ethernet cards (6)

Peripherals at Maine:

Disk Drive for Gateway 2000 personal computer
 ESDI Hard Drive Controller
 Hewlett Packard Paint Jet plotter
 Micropolis 153 hard drives (2)
 QFA-700 Tape Drive
 Panasonic printer
 Digitizing tables (2)
 Hewlett Packard plotter

Software Received at Maine:

Microsoft Windows 3
 Microsoft Word for Windows
 Turbo C++
 Turbo C++ Professional
 Exodus Database Program
 Intergraph GIS, Image Processing, and System Software Upgrades
 Norton Utilities 5.0
 Borland C++

GatorSystem Release 2.0 Upgrade
 Turbo C++
 RightWriter for the Mac
 PC ARC/INFO licenses (8)
 Taste 1.0
 Application Frameworks 1.0
 1meg memory for Mac Plus (2)
 Novell 2.2

Hardware and Software Received at Santa Barbara

1 Memory Expansion Board for PS/MOD
 10 MB-SIMM for PS 2, Model 70 Motherboard
 2 FAX machines, Toshiba TF 251
 1 Copier, Sharp SE 8300
 1 Seiko Color Point PS Model 4
 1 Seiko Color Point Printer
 1 Complete Communicator
 1 Chinon converter (DOS/MAC)
 2 ADT/702A Seagate External Drives + Cables
 1 Pagemaker 4.0
 1 Motif 2901 for IBM RS/6000
 1 WordPerfect 5.0
 1 FXII MAC, keyboard and monitor
 2 Token ring cards
 1 Deskwriter 2279-A
 Interleaf IBM RS/6000 software
 1 Matrix QCR Z camera, camera backs
 Gatorbox Upgrade 2.0
 Hewlett Packard Deskwriter
 Voltage control

APPENDIX 1 - PUBLICATIONS

A. Articles published or formally accepted in refereed journals

- Anselin, L. and A. Getis (in press) Spatial statistical analysis for geographic information systems. *Annals of Regional Science*.
- Anselin, L. and S. Rey (1991) Properties of tests for spatial dependence in linear regression models. *Geographical Analysis* 23(2): 112-131.
- Anselin, L. and J. O'Loughlin (1991) Bringing geography back to the study of international relations: spatial dependence and regional context in Africa, 1966-78. *International Interactions* 17(1): 29-61.
- Appelbaum, R. and P. Dreier (1991) American nightmare: homelessness. *Challenge* 34(2): 46-52.
- Appelbaum, R. (1991) Scapegoating rent control: masking the causes of homelessness. *Journal of the American Planning Association* 57(2): 153-164.
- Armstrong, M.P., P.J. Densham, P. Lolonis and G. Rushton (in press) Cartographic displays to support locational decision-making. *Cartography and GIS*.
- Armstrong, M.P., G. Rushton, R. Honey, B. Dalziel, P. Lolonis, S. De and P.J. Densham (1991) Decision support for regionalization: a spatial decision support system for regionalizing service delivery systems. *Computers, Environment and Urban Systems* 15(1): 37-53.
- Batty, M. (1990) Editorial: Intelligent cities: using information networks to gain competitive advantage. *Environment and Planning B* 17: 247-56.
- Batty, M. (1990) Comment on Harris: Planning support systems and the emerging technological environment for urban and regional planning. *Regional Development Dialogue* 11: 58-62.
- Batty, M. (1991) Generating urban forms from diffusive growth. *Environment and Planning A* 23: 511-44.
- Batty, M. (1991) Computers and planning: old ideas, new tools. *Environment and Planning B* 18: 135-37.
- Batty, M. and A.G. Yeh (1990) Guest Editorial: Applications of geographic information systems to urban and regional planning. *Environment and Planning B* 17: 369-74.
- Batty, M. and A.G. Yeh (1991) The promise of expert systems for urban planning. *Computers, Environments, and Urban Systems* 15(3): 101-8.
- Beard, M.K. (in press) Theory of a cartographic line revisited: Implications for automated generalization. *Cartographica*.
- Benwell, G.L. and H.J. Dickinson (1991) Software requirements for Petri nets in the behavioral analysis of spatial information. *New Zealand Surveyor* 33: 64-79.
- Bloxham, C.A. and R.L. Church (1991) The P-median scheduling and location problem. *Papers in Regional Science* 1(1): 21-36.
- Butenfield, B.P. (in press) Statistical analysis of responses from an American Cartographic Association member survey. *Cartography and GIS*.
- Butenfield, B.P. (in press) Review of Clarke, K.C., *Analytical and Computer Cartography* (Wiley and Sons, New York, 1990). *Progress in Human Geography*.
- Butenfield, B.P. (in press) Review of Tomlin, C.D., *Geographic Information Systems and Cartographic Modeling* (Prentice Hall, Englewood Cliffs NJ, 1990). *Cartography and GIS*.
- Buyong, T. and W. Kuhn (in press) Local adjustment for measurement-based cadastral systems. *Surveying and Land Information Systems*.

- Buyong, T., W. Kuhn and A.U. Frank (in press) A conceptual model of measurement-based multipurpose cadastral systems. *Journal of the Urban and Regional Information Systems Association*.
- Calkins, H.W. and H.J. Dickinson (1990) Concerning the economic evaluation of implementing a GIS. *International Journal of Geographical Information Systems* 4(2): 211-12.
- Calkins, H.W. and N. Obermeyer (in press) Value of information, taxonomies of information use, and diffusion of technology. *Journal of the Urban and Regional Information Systems Association*.
- Calkins, H.W. and N. Obermeyer (1991) Taxonomy for surveying the use and value of geographical information. *International Journal of Geographical Information Systems* 5(3): 341-351.
- Church, R.L, J. Current and J. Storbeck (in press) A bicriterion maximal covering location formulation which considers the satisfaction of uncovered demand. *Decision Sciences*.
- Couclelis, H. (in press) Editorial: There is nothing as theoretical as good practice. *Environment and Planning B*.
- Davis, F.W., D. Stoms, C. Cogan, M. Painho, B. Duncan, J. Scepan and M. Scott (in press) Geographic information systems analysis of species sighting data: a case study of the California Condor. *Photogrammetric Engineering and Remote Sensing*.
- Davis, F.W., D. Schimel, M. Friedl, R. Dubayah, T. Kittle and J. Dozier (in press) Biophysical stratification of a tallgrass prairie for integration of ground and satellite data. *Journal of Geophysical Research*.
- Davis, F.W., D. Quattrochi, M. Ridd, N. Lam, S. Walsh, J. Michaelsen, J. Franklin, D. Stowe, C. Johannsen and C. Johnston (1991) Environmental analysis using integrated GIS and remotely sensed data: some research needs and priorities. *Photogrammetric Engineering and Remote Sensing* 57: 689-697.
- Davis, F.W. and J.E. Estes (in press) Improved integration of remote sensing and geographic Information systems: a background to NCGIA Initiative 12. *Photogrammetric Engineering and Remote Sensing* 57(6): 643-645.
- Ding, Y. and A.S. Fotheringham (in press) The integration of spatial analysis and GIS. *Computers, Environment and Urban Systems*.
- Eagles, M. (in press) Review of R. Levy, *Scottish Nationalism at the Crossroads* (Scottish Academic Press, 1990). *West European Politics*.
- Egenhofer, M.J. (1990) Interaction with geographic information systems via spatial queries. *Journal of Visual Languages and Computing* 1(4): 389-413.
- Egenhofer, M.J. and R. Franzosa (1991) Point-set topological spatial relations. *International Journal of Geographical Information Systems* 5(2): 161-174.
- Egenhofer, M.J. (in press) Why not SQL! *International Journal of Geographical Information Systems*.
- Egenhofer, M.J. (1991) Extending SQL for graphical display. *Cartography and Geographic Information Systems* 18(4): 230-245.
- Egenhofer, M.J. and A.U. Frank (in press) Object-oriented modeling for GIS. *Journal of the Urban and Regional Information Systems Association*.
- Ehlers, M. (1991) Multisensor image fusion techniques in remote sensing. *ISPRS Journal of Photogrammetry and Remote Sensing* 46: 19-30.
- Ehlers, M. (1990) Remote sensing and geographic information systems: towards integrated spatial information processing. *IEEE Transactions on Geoscience and Remote Sensing* 28(4): 763-766.
- Fotheringham, A.S. (1990) Review of J. Sutton, *Transport Coordination and Social Policy*. *Annals of Regional Science* 24(1): 77-8.
- Fotheringham, A.S. (1991) GIS and spatial analysis: an NCGIA research initiative. *Commentary in Environment and Planning A* 23(10): 1390-91.
- Fotheringham, A.S. (1991) Review of J. Hauer, H. Timmermans and N. Wrigley, editors, *Urban Dynamics and Spatial Choice Behavior* (Kluwer, Dordrecht, 1990). *Tijdschrift voor Economische en Sociale Geografie* 82(2): 157.

- Fotheringham, A.S. (1991) Some random(ish) thoughts on spatial decision support systems. *Environment and Planning A* 23(12): 1699-700.
- Fotheringham, A.S. (in press) Review of M.M. Fischer, S. Nijkamp and Y.Y. Papageorgiou, Spatial Choices and Processes. *Journal of Regional Science*.
- Fotheringham, A.S. (in press) Review of K. Jones and J. Simmons, The Retail Environment. *Annals of Regional Science*.
- Fotheringham, A.S. (in press) Review of J. de D. Ortuzar and L. G. Willumsen, Modelling Transport. *Environment and Planning A*.
- Fotheringham, A.S. (in press) Review of S. Erlander and N. F. Stewart, The Gravity Model in Transportation Analysis: Theory and Extensions. *Environment and Planning B*.
- Fotheringham, A.S., M. Batty and P. Longley (1989) Diffusion-limited aggregation and the fractal nature of urban growth. *Papers of the Regional Science Association* 67: 55-69.
- Fotheringham, A.S. and D.W-S. Wong (1991) The modifiable areal unit problem in multivariate statistical analysis. *Environment and Planning A* 23(7): 1025-44.
- Frank, A.U. (in press) Acquiring a digital base map: a theoretical investigation into a new form of sharing data. *Journal of the Urban and Regional Information Systems Association*.
- Frank, A.U. and M.J. Egenhofer (in press) Computer cartography for GIS: an object-oriented view on the display transformation. *Computers and Geosciences*.
- Frank, A.U., M.J. Egenhofer and W. Kuhn (1991) A perspective on GIS technology in the nineties. *Photogrammetric Engineering and Remote Sensing* 57(11): 1431-1436.
- Franklin, J., F.W. Davis and P. Lefebvre (1991) Thematic Mapper analysis of tree cover in semiarid woodlands using a model of canopy shadowing. *Remote Sensing of Environment* 36: 189-202.
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- Goodchild, M.F. (1991) Geographic information systems. *Progress in Human Geography* 15(2): 194-200.
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- Goodchild, M.F. and K.K. Kemp (in press) NCGIA education activities: the Core Curriculum and beyond. *International Journal of Geographical Information Systems*.
- Goodchild, M.F. and V.T. Noronha (in press) Modeling interregional interaction: implications for defining functional regions. *Annals, Association of American Geographers*.
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- Jelinski, D.E. (1991) On the use of chi-square analyses in studies of resource utilization. *Canadian Journal of Forest Research* 21(1): 58-65.
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- Kemp, K.K., M.F. Goodchild and R.F. Dodson (in press) Teaching GIS in geography. *Professional Geographer*.
- Klinkenberg, B. and M.F. Goodchild (in press) Tests of a fractal model of topography. *Earth Surface Processes and Landforms*.
- Lanter, D. (in press) A lineage-based meta-database for GIS. *Cartography and GIS*.
- Lanter, D. and H. Veregin (in press) A research paradigm for propagating error in layer-based GIS. *Photogrammetric Engineering and Remote Sensing*.
- Lindner-Dutton, L., R. Batta and M.H. Karwan (1991) Equitable sequencing of a given set of hazardous materials shipments. *Transportation Science* 25: 124-37.
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- Mark, D.M. and M.D. Gould (1991) Interacting with geographic information: A commentary. *Photogrammetric Engineering and Remote Sensing, Annual Special Issue on GIS* 57(11): 1427-1430.
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- Onsrud, H., J. Pinto and B. Azad (in press) Case study research methods for geographic information systems. *Journal of the Urban and Regional Information Systems Association*.
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- Stoms, D., F.W. Davis and C. Cogan (in press) Sensitivity of wildlife habitat models to uncertainties in GIS data. *Photogrammetric Engineering and Remote Sensing*.
- Stoms, D.M., F.W. Davis, C. Cogan, M. Painho, B. Duncan, J. Scepan and M. Scott (in press) Geographic analysis of California condor sighting data. *Conservation Biology*.
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- Weaver, J.R. and R.L. Church (1991) The nested hierarchical median facility location model. *Infor* 29(2): 100-115.
- Weibel, W.R. and B.P. Buttenfield (in press) Improvement of GIS graphics for analysis and decision-making. *International Journal of Geographical Information Systems*.
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B. Books

- Appelbaum, R. and J. Henderson (in press) *States and Development in the East Asian Pacific Rim*. Sage.
- Brothie, J., M. Batty, P. Hall and P. Newton, editors (1991) *Cities of the 21st Century: New Technologies and Spatial Systems*. Longman Group, London and Halsted Press, New York.
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Weber, C. (1991) A screen-reflection algorithm for calculating buffer distances in raster images. *Technical Papers, ACSM/ASPRS Annual Convention, Baltimore MD 2*: 325-32.

Willer, D.J. (1990) A spatial decision support system for bank location. *Technical Report 90-9*. National Center for Geographic Information and Analysis, Santa Barbara CA.

E. Articles submitted and under consideration by refereed journals, refereed conference proceedings and books

Armstrong, M.P. and P.J. Densham, Domain decomposition for parallel processing of spatial problems. *Computers, Environment, and Urban Systems* (under consideration).

Butenfield, B.P. and J.S. DeLotto, Multiple representations of digital data: a data set for teaching and research. *Photogrammetric Engineering and Remote Sensing* (under revision).

Batta, R. and S. Chiu, Further developments on the connection between network and planar Manhattan metric location topologies. *Networks* (under consideration).

Batta, R. and D. Malon, The traveling repairperson home base location problem. *Transportation Science* (under consideration).

Batta, R., S. Prasad and V. Viswanathan, A postmortem analysis of a common locational decision for emergency service facilities. *Operations Research* (under consideration).

Church, R.L., A. Rathi and R. Solanki, Allocating resources to support a multicommodity flow with time windows. *The Logistics and Transportation Review Journal* (under consideration).

Church, R.L. and R. Davis, The fixed charge maximal covering location problem. *Papers in Regional Science* (under consideration).

Church, R.L. and A. Murray, Modeling school utilization and consolidation. *Journal of Urban Planning and Development* (under consideration).

Church, R.L., S. Loban and K. Lombard, Exploring spatial alternatives for a corridor location problem. *Computers and Geosciences* (under consideration).

Church, R.L., A.T. Murray and R.A. Gerrard, The reliability of 'alpha reliability'. *Transportation Science* (under consideration).

Dell, R.F., R. Batta and M.H. Karwan, Equitable vehicle routes for overnight parcel deliveries. *Operations Research* (under consideration).

Densham, P.J. and G. Rushton, A more efficient heuristic for solving large p-median problems. *Papers in Regional Science* (under revision).

Eagles, D.M., The political ecology of campaign contributions: a constituency-level analysis. *Canadian Journal of Political Science* (under revision).

Eagles, D.M. and S. Erfle, Explaining third/minor party voting in England: one-party dominance and community cohesion perspectives. *European Journal of Political Research* (under revision).

Gerrard, R.A. and R.L. Church, Analyzing tradeoffs between zonal constraints and accessibility in facility location. *Computers and Operations Research* (under consideration).

Goodchild, M.F., Geography and statisticians. *The Operational Geographer* (under consideration).

Goodchild, M.F., B. Klinkenberg and D.G. Janelle, A factorial model of aggregate spatio-temporal behavior: application to the diurnal cycle. *Geographical Analysis* (under revision).

Goodchild, M.F. and Yang Shiren, Properties of Morton and generalized digit interleaved orderings for geographical databases. *Computers and Geosciences* (under consideration).

- Goodchild, M.F., Geographic information science. *International Journal of Geographical Information Systems* (under consideration).
- Gould, M.D. and P.J. Densham, Spatial decision support systems for environmental management: oil spill response. *Environmental Management* (under consideration).
- Holmes, J.H., G. Rushton and P.J. Densham, Cost-utility appraisal of rural settlement and servicing networks in Australia's pastoral zone. *Journal of Rural Studies* (under consideration).
- Jelinski, D.E. and W.M. Cheliak, Spatial subdivision of *Populus tremuloides* in a heterogeneous environment. *American Journal of Botany* (under revision).
- Jin, H. and R. Batta, Criteria and models for hazardous materials routing: a probabilistic perspective. *Operations Research* (under consideration).
- Lanter, D., Complementary functions for aiding spatial analytic database management. *Cartography and GIS* (under consideration).
- Sivakumar, R., R. Batta and M. Karwan, A network-based model for transporting extremely hazardous materials. *Operations Research Letters* (under consideration).
- Tobin, R.J. and D.M. Eagles, US and Canadian attitudes toward international actions: A cross-national test of the double-standard hypothesis. *Basic and Applied Social Psychology* (under revision).
- Weber, C.R. and B.P. Battenfield (1991) Cartographic animation of average yearly surface temperatures for the 48 contiguous states: 1897 - 1976. *Cartography and GIS* (under consideration).

APPENDIX 2 - PRESENTATIONS BY NCGIA PERSONNEL

January: Ricardo Moreno, graduate research assistant, visited nine schools, filmed a public TV service announcement, appeared on a radio talk show, two TV news programs, and three eyewitness news spots, in an effort to promote math and science opportunities to younger students in Corpus Christi, TX.

January 14: Michael Goodchild presented "GIS and Environmental Modeling" at IIPS, New Orleans, Louisiana.

January: Richard Church presented two papers coauthored with A. Rathi and R. Solanki, "Allocating Resources to Support a Multicommodity Flow with Time Windows" and "A Macro-Level Analysis of the Airlift Deployment Problem", at the Transportation Research Board's 70th Annual Meeting in Washington DC.

January 2-5: Stewart Fotheringham was the invited guest of the Quantitative Methods Specialty Group of the Institute of British Geographers at the Annual Conference of the IBG in Sheffield, UK. Fotheringham discussed papers on chaos theory.

January 11: Michael Goodchild made a presentation to the Ontario Standard Labelled Road Network Group on a proposed standard for centerline databases, in Toronto.

January 14: Kate Beard gave a presentation and update on NCGIA activities to the New England Chapter of URISA, Boston, MA.

January 24: Michael Goodchild was the lunchtime speaker at the South Carolina State Mapping Advisory Group meeting in Columbia, and gave a presentation to the Department of Geography, University of South Carolina.

February 4: Michael Goodchild and Richard Church visited California Polytechnic University, San Luis Obispo, to discuss use of GIS in intelligent highway systems.

February 8: Werner Kuhn (in place of Kate Beard) gave an invited talk at the Constituting Meeting of the Massachusetts Association of Land Surveyors and Civil Engineers GIS Committee, Marlborough, MA.

February 20: Matt McGranaghan presented a talk "Toward a Model of Simultaneous Color Contrast in Map Displays", University of Maine, Orono.

March 1-11: Werner Kuhn traveled to Germany to investigate the state and needs of cadastral and topographic information management in the five new states.

March 4: David Mark presented an Initiative 2 overview paper to the Geography Department, University of Connecticut.

March 2-5: Kate Beard visited the Departments of Geography, Landscape Architecture, and Forestry, and the Center for Remote Sensing, University of Oklahoma, Stillwater, Oklahoma. She gave a presentation on research in GIS and NCGIA.

March 6: Michael Goodchild visited the University of Maryland, spoke on "Accuracy of Spatial Databases" to the Department of Geography and appeared on a panel at the Mid-Atlantic regional meetings of the Association of American Geographers.

March 11 and May 13: Stewart Fotheringham visited the corporate headquarters of Hallmark Cards, Kansas City, to discuss research on developing a Spatial Decision Support System for Retail Location.

March 13-14: Michael Goodchild met with research and management personnel at the Macaulay Institute in Aberdeen and the Scottish Office in Edinburgh, Scotland, to discuss long range GIS planning.

March 17-18: Michael Goodchild attended a workshop on integrating GIS and spatial analysis at the University of Sheffield.

March 19: Hugh Calkins and Mike Batty visited the New York City Metropolitan Transit Commission Offices in New York to discuss the development of land use and transportation models in GIS development for the Tri State Region of New York, Connecticut, and New Jersey.

March 22-24: Michael Goodchild presented "GIS and Social Science", Luc Anselin spoke on "SpaceStat, A Program for the Statistical Analysis of Spatial Data", Stewart Fotheringham presented "GIS and Spatial Analysis: The Modifiable Areal Unit Problem Revisited", and Ezra Zubrow and Inger Marie Holm-Olsen presented "Ideal Settlement Pattern and Real Topography: Anthropological and Archaeological Issues" at the NCGIA-sponsored "GIS in the Social Sciences" conference in Santa Barbara.

March: A special session was organized by Santa Barbara NCGIA (Jack Estes, Jeff Star) at the Baltimore March 1991 ACSM/ASPRS/Auto Carto 10 Annual Convention. Eighteen papers were presented. Jeff Star and Frank Davis chaired the morning session on NCGIA. The AutoCarto 10 meeting was co-organized by David Mark, and included a session on Initiative 7 organized by Kate Beard and Barbara Battenfield. Michael Goodchild appeared in two panel discussions.

March: Frank Davis, Jeff Star and Michael Goodchild spoke about GIS and its applications to a meeting of the Western Association of Map Librarians at UC Santa Barbara.

March: Frank Davis spoke on "Modeling Species Distributions Using Digital Satellite and Terrain Data" at the Department of Botany, University of Wyoming-Laramie.

April 1: Matt McGranaghan presented "Further Explorations of the Choropleth Map," at NCGIA-Buffalo, Buffalo, NY.

April 1-4: Karen Kemp and Michael Goodchild attended the European GIS conference in Brussels. Kemp presented a workshop on the Core Curriculum, and Goodchild gave a keynote address.

April 9: Karen Kemp and Michael Goodchild met with the GIS group at EPA Las Vegas to discuss joint research under the cooperative agreement with NCGIA.

April 10-12: Luc Anselin presented "Is the World System Devolving to Regional Sub-Systems? An Exploratory Spatial Analysis of the Trade and Political Relations of the US, W. Germany and Japan, 1966-88" (with J. O'Loughlin) at the IGU Commission on Political Geography, Conference on Global Political Change at Florida State University, Tallahassee.

April 11-13: Paul Densham and J. Barkan presented an invited paper entitled "Decision Support for Planning the Location of Social Service Facilities: A New System in Mysore, India", at the Symposium on Microcomputers for International Development: New Applications in Planning and Management, The Institute for African Development, Cornell University.

April 13-17: At the 1991 Annual Meetings of the Association of American Geographers in Miami, FL, Matt McGranaghan presented "Interaction Between Map Legend and Background Value". David Mark was a panelist in a panel discussion entitled "User Interfaces for Geographic Information Systems II: Possible Solutions". Mark also co-organized and chaired the earlier panel: "User Interfaces for Geographic Information Systems I: User Needs" that same day. Michael Goodchild gave a workshop on data quality with Peter Fisher of Kent State University and appeared in two panel discussions. David Mark presented a paper, "Re-Constructing the Map: Experiential Realism, Image-Schemata, and Spatial Cognition". The meetings included a special session on Initiative 12, and John Estes, Jeff Star, Dale Quattrochi, Nick Faust and Manfred Ehlers participated.

April: Terry Smith gave the keynote address at the April 1991 "Swedish Map Days" meeting for the Swedish Cartographic Society.

April 20: Kate Beard gave a keynote presentation for the Boston Society of Civil Engineers on "History and Future Trends in GIS," Boston, MA.

April 23: Karen Kemp and Michael Goodchild visited ESRI in Redlands, CA to discuss the development of the ESRI GIS Concepts Kit.

April 29: David Steiner, graduate student in the Department of Surveying Engineering, presented "The Production of Digital Orthophotos on a Microcomputer," at the James W. Sewall Company's "GIS Luncheon Seminar" series, Old Town, ME.

April 30: David Mark and Werner Kuhn led a Special Interest Group meeting entitled "User Interfaces for Geographic Information Systems", ACM Computer-Human Interaction meeting (CHI'91), New Orleans, Louisiana.

May 3: Andrew Frank presented "Spatial Concepts, Geometric Models, and Data Structures," at the Center for Mapping, Ohio State University, Columbus, OH.

May 6-11: Sarah Clapham attended the workshop, Data Visualization Techniques in Environmental Management, Las Vegas, NV.

May 13: Karen Kemp and Michael Goodchild made presentations at the IBM Academic Computing Conference in Dallas.

May 14-18: Andrew Frank and Terence Smith attended the Basic Goods Conference, Capri, Italy, and presented papers on Initiative 5 research.

May 13-15: Paul Densham and G. Rushton presented a paper entitled "A Knowledge-Based Spatial Decision Support System for Locational Decision-Making" at a special session on Spatial Decision Support Systems sponsored by the The Institute of Management Scientists' College on Locational Analysis, Fall Meeting of the Operations Research Society of America and The Institute of Management Scientists, Nashville, TN. "A Heuristic for the Equity Constrained Multiple Traveling Salesman Problem with Time Windows" was presented by Rajan Batta. Richard Church presented "The Relationship of the Fleet and MoFleet Location Models" (with J.R. Weaver) and "P-Median Problem with Overlapping Zonal Constraints" (with R. A. Gerrard).

May 20-23: David Mark and Michael Gould were panelists in a discussion entitled "User Interfaces for GIS", at the ESRI User Conference, Palm Springs, California. The panel was organized by M. Gould. Michael Goodchild gave a workshop on spatial data quality.

May 22: Renato Barrera gave a talk "Approximate Queries in Geographic Information Systems," at Jackson Laboratories, Bar Harbor, ME.

May 23: Paul Densham presented an invited paper entitled "The Role of The National Center for Geographic Information and Analysis" at the Conference on Geographic Information Systems, Inteligis Corporation, Buffalo, NY.

June 3: Several NCGIA-Buffalo researchers and students presented papers at the Canadian Cartographic Association annual meeting, co-sponsored by NCGIA-Buffalo, and on-site in Buffalo on June 3. Paper presentations included: Barbara Buttenfield, "Automatic scale changing and rule-based systems"; Michael Gould, "User interfaces for geographic information systems"; David Mark, "Experiential realism, spatial cognition, and maps"; Chris Weber, "A screen-reduction algorithm for calculating buffer distances in raster images". Center researchers and students also presented software and hardware demonstrations for conference participants.

June: Frank Davis spoke on "Beyond endangered species: gap analysis of biodiversity in California" at the Sigma Xi Annual Banquet, California State University at Northridge.

June: Frank Davis presented "Digital geographic data for assessing effects of global climate change on BLM lands" to the Bureau of Land Management Workshop on Global Change Research, Fort Collins, Colorado.

June: Frank Davis was workshop organizer and participant for the "Gap Analysis Workshop", a US Fish and Wildlife Service workshop for Gap Analysis investigators, Santa Barbara.

June: Michael Goodchild was the keynote speaker at a two day symposium on spatial database error in Melbourne, Australia. He also presented seminars at the Universities of Canterbury and Otago in New Zealand.

June: A paper by David Lanter and Howard Veregin, "Error Propagation in GIS Applications", was presented at the Canadian Association of Geographers' Annual Meeting in Kingston, Ontario.

July 1: Mike Batty visited the Institute for Transportation of the City University of New York (CUNY) and discussed possibilities for joint work on transportation modeling and GIS in the New York Tri-State Region with Buz Paaswell and Norbert Openheim.

July 6-8: Mike Batty acted as co-organizer of the Second International Conference on Computers in Urban Planning and Management held at Oxford and presented a paper, "Creating Visual Environments for Simulating Urban Structure". Papers from this meeting are to be published in "Environment and Planning B", in 1992, guest edited by Lyna Wiggins.

July 8-9: Andrew Frank presented "From the Database to Graphics Transformation of Data Models," at the GIS and Cartography - Theoretical Foundations and Future Aspects conference, University of Vienna, Austria.

July: Michael Goodchild visited the University of Cape Town, University of Pretoria and the University of Witwatersrand, and gave a keynote address at the South African GIS conference in Pretoria.

July 18: Andrew Frank met with Intergraph Corporation and presented an overview of NCGIA project work which Intergraph has helped support.

July 20 - August 7: Mike Batty attended the United Nations Center for Regional Development (UNCRD-CAP) Training Course on GIS in Local/Regional Planning and presented four lecture sessions on: "The use of IT and GIS in Regional and Local Planning"; "GIS and Planning Applications"; "GIS in Forecasting and Prediction"; and "GIS in Plan Generation and Evaluation".

July 24-27: Mike Batty visited the Urban Planning Bureau's Automation Center in Guangzhou (Canton) PRC and presented lectures on "The use of urban and transportation models and information systems in urban planning".

July 25: Mike Batty met with Paul Stott of the World Bank's Resident Mission in China in Guangzhou, PRC and discussed problems of land information systems in large Chinese cities, and the ways in which GIS and computers generally might be used to inform such work.

July 25-26: Barbara Battenfield visited Microsoft Corporation in Redmond, Washington to discuss opportunities for industrial affiliation with the Center.

July 30: Harlan Onsrud presented "Legal Issues Pertaining to GIS," at the James W. Sewall Company, Old Town ME.

July: Michael Goodchild participated in a workshop on the selection of digital databases for the National Archives in Washington DC.

July: Frank Davis spoke on "Spatial statistics" and "Simulating fire regime in heterogeneous landscapes" at the National Science Foundation Summer Course on Patch Dynamics in Terrestrial and Marine Ecosystems, Cornell University.

July - August: Paul Densham carried out cooperative research at the India Institute of Management at Bangalore, including fieldwork in the Mysore district. He jointly organized and participated in an international expert group meeting to evaluate the use of spatial analysis and spatial decision support systems in rural service planning.

August 5-9: Michael Goodchild gave a Workshop on GIS and Spatial Analysis at Environmental Systems Research Institute, Redlands CA.

August 8: Paul Densham, Gerard Rushton and V.K. Tewari presented a talk entitled "A Spatial Decision Support System for Improving Access to Rural Services" at the National Informatics Centre, New Delhi, India.

August 11: Harlan Onsrud chaired the Land Surveys Committee Meeting of the American Bar Association, Real Property Section, Atlanta, GA.

August 12-15: Harlan Onsrud, Michael Goodchild, Karen Kemp and Jeffrey Pinto attended the URISA meeting in San Francisco. Onsrud gave a talk on "Case Study Research Methods for GIS", and chaired a special interest group meeting on education in technology transfer. Goodchild participated in sessions on spatial decision support systems and gave a workshop on GIS and spatial analysis. Kemp participated in a panel on GIS education.

August 12-23: Andrew Frank attended the IAG meeting in Vienna with the UGG World Congress.

August 14-29: Stewart Fotheringham presented a paper entitled "The Modifiable Areal Unit Problem and Location-Allocation Modelling" at the European Regional Science Meetings in Lisbon in a special set of sessions on GIS and Spatial Analysis. He was also a discussant on two papers in those sessions. Before and after the RSA meetings, Fotheringham met with various people from the Regional Research Laboratories in the UK about the upcoming I-14 specialist meeting, funding, participation, and organization. Luc Anselin presented "Spatial statistical analysis and GIS" (with A. Getis) at the same meeting.

August 19-23: David Tyler, Max Egenhofer, Steven Frank, Todd Rowell, Gary Volta, Langley Willauer, Barbara Bicking and Wen-Shu Liou attended the Third Annual Meeting of the Atlantic Institute at the University of Laval, Quebec, Canada. Tyler presented "Research in the Department of Surveying Engineering" and Egenhofer gave an overview of the activities in the NCGIA. He also presented "A Temporal Cadastral System" by Khaled Al-Taha, NCGIA graduate research assistant. Volta presented

"Exploring GIS Attribute Data," and Willauer presented "A Report on the NCGIA Specialist Meeting on Human Interfaces for GIS." Tyler and Egenhofer also participated in a panel discussion on "GIS Research Needs in Industry and Government."

August 22-23: Michael Goodchild participated in a Workshop on 3D GIS, Breckenridge CO.

August 28-30: Andrew Frank presented "Properties of Geographic Data Requirements for Spatial Access Methods," and a paper by Max Egenhofer, "Reasoning about Binary Topological Relations," at the Second Symposium on Large Spatial Databases, Zurich, Switzerland.

August 25-31: Luc Anselin attended the international conference on East Europe-Central Europe-Europe, IGU Commission on the World Political Map, Prague, Czechoslovakia.

September 11-15: Luc Anselin presented "Elements of a spatial analysis module for general purpose GIS" (with A. Getis) and "Trade, aid, conflict and cooperation: an analysis of soviet international interactions" 1966-88 (with J. O'Loughlin) at the Association of Pacific Coast Geographers annual meeting in Tucson AZ.

September 17: Michael Goodchild made a presentation to the League of California Cities, San Francisco, on regionalizations for California.

September 15-19: Paul Densham and Dennis Jelinski attended the NCGIA-sponsored First International Conference/Workshop on Integrating Geographic Systems and Environmental Modeling in Boulder, Colorado. Densham presented an invited paper, "Briefing on NCGIA Initiative 6". Joel Michaelsen, Luc Anselin and Michael Goodchild made presentations, and the conference was also attended by several graduate students from Santa Barbara.

September 18: Andrew Frank attended the International Federation of Surveyors (FIG) Symposium 1991, Innsbruck, Austria.

September 19: Michael Goodchild and Hoyt Walker made presentations at a symposium on "What is Scientific GIS?", organized by IBM Corp in Boulder CO.

September 20: Kate Beard gave presentations on GIS and the NCGIA for the University of Maine College of Engineering's "Tour of Tomorrow," Orono, ME.

September 23-30: Kate Beard and William Mackaness attended the International Cartographic Association Conference, Bournemouth, England. Beard presented the paper "User Interaction in Map Generalization" as part of a special interest group session on generalization. Barbara Buttenfield presented a paper, co-authored with William Mackaness, on "Incorporating Time into Geographic Process: A Framework for Analyzing Process in GIS".

September 25: David Tyler attended the ASPRS 1991 Symposium on GIS and Supporting Technologies, Salem State College, Salem, MA, and presented "An Overview and Progress Report of the NCGIA Research Program."

September 29 - October 4: Werner Kuhn attended the International Federation for Information Processing 2nd Working Conference on Visual Database Systems, Budapest, Hungary, and presented the paper "Visualizing Spatial Query Results: The Limitations of SQL," Max Egenhofer co-author.

September: Frank Davis presented "Integrating plots, maps and images for regional environmental monitoring and modeling" at the Fourth Biennial Conference of Research in California's National Parks, University of California, Davis.

October 6-9: Max Egenhofer attended the ACM SIG Board meeting, Phoenix, AZ, to propose the formation of a Special Interest group on spatial data.

October 7: Michael Goodchild presented an introduction to GIS at the annual meeting of IAMSLIC in Galveston TX.

October 9: David Mark delivered a talk, "Interacting with Geographic Information", to the Department of Geography at the University of California at Santa Barbara.

October 16-24: Paul Densham visited the Environmental Systems Research Institute in Redlands,

CA, to work with researchers there to develop a conceptual design for future versions of ARC/INFO's NETWORK module. On October 17, Densham presented an invited paper, "Developments in Heuristic Location-Allocation Modelling" at the ESRI Forum.

October 21-22: Kate Beard attended the 6th Annual Northeast ARC/INFO User Group Conference, Portland, ME, and made an opening presentation on NCGIA-Maine current research activities.

October 24: Andrew Frank visited Intergraph, Reston, VA.

October 25-26: Michael Goodchild and Karen Kemp attended the GIS in Higher Education conference at the University of South Florida, Tampa.

October 28: Michael Goodchild spoke on "Accuracy of Spatial Databases" at the Department of Geography, University of Georgia.

October 26-30: Barbara Buttenfield, Peter Rogerson, Hui Lin, Karen Kemp, Michael Goodchild and Chris Weber attended the GIS/LIS '91 meetings in Atlanta. Buttenfield and Weber presented "How does a Cartographic object behave? Computer inventory of topographic maps" (co-authored with M. Leitner, J.J. Phelan, D.M. Rasmussen and G.R. Wright). Lin presented "Spatio-Temporal Intersection (STIN) and volumetric modeling" (co-authored with David Mark). Rogerson presented a paper (not to be published in the proceedings) co-authored with Stewart Fotheringham, "Problems in Spatial Analysis from a GIS Perspective". Three other papers with NCGIA-Buffalo authorship were presented: Armstrong, Densham, and Lolonis, "Cartographic visualization and user interfaces in spatial decision support systems"; Freundsuh and Gould, "Empirical user testing for validation of GIS design"; McMaster and Mark, "The design of a graphical user interface for knowledge acquisition in cartographic generalization". Goodchild and Kemp presented workshops, and Goodchild made two panel presentations.

October: Frank Davis presented "Gap analysis of biodiversity in California" at a Symposium on Biodiversity in Northwestern California, Santa Rosa.

October 28 - November 1: Khaled Al-Taha and Harlan Onsrud attended GIS/LIS 1991, Atlanta, GA. Al-Taha presented the papers "Time Perspectives in a GIS: As Applied to Cadastral Systems," Andrew Frank co-author, in the session "Building a Digital Cadastre," and "Symbol Density as a Design Parameter in Cartographic Expert Systems," Matt McGranaghan, Carlos Paramo, and Andrew Frank authors.

October 29: Harlan Onsrud attended the National Association of Counties Research and Technology Focus Group's First GIS Symposium, Raleigh, NC. He also met with Allan Bromley, White House Science Advisor.

November 2-7: Paul Densham attended the Fall Meeting of the Operations Research Society of America and The Institute of Management Scientists in Anaheim. He presented "Model-base Management in Spatial Decision Support Systems for Locational Planning" as a special session on Spatial Decision Support Systems sponsored by the Institute of Management Scientists' College on Locational Analysis. "An Undesirable Facility Location Problem with Mixed Norms" and "Routing Extremely Hazardous Materials: Minimization of Conditional Risk" were presented by Rajan Batta. On November 6, Densham presented an invited paper, "Spatial Decision Support Systems: Developments in Model Management", to the Department of Geography Colloquium at San Diego State.

November 4-5: Kate Beard attended a Lincoln Institute for Land Policy sponsored two-day workshop on "Using GIS to Manage Urban Growth and Change," Cambridge, MA, and made a presentation on Future Developments in GIS.

November 7-11: Stewart Fotheringham, Peter Rogerson, Rajan Batta, Sam Cole, Luc Anselin and Alex Anas attended the North American Regional Science Association in New Orleans. Rogerson co-authored two papers for the meeting, "The Spatial Separation Between Parents and Their Adult Children" (with R. Weng) and "Optimal Sequential Spatial Search" (with M. Harwitz, B. Lentnek, and T. Smith). Batta presented an I-6 related paper, co-authored with E. Erkut, "A Multicriteria, Mixed-Norm Location Model for a Hazardous Waste Dump Site". Fotheringham presented a paper co-authored with S. Trew, "Modeling Store Choice: Chain Recognition and Market Segmentation". Britton Harris, who had been in residence at the NCGIA-Buffalo in October, presented a paper co-authored with Mike Batty, "Location Models in Geographic Information and Planning Support Systems". "An Undesirable Facility Location Problem with Mixed Norms" was presented by Rajan Batta.

November 11-12: Mike Batty attended UNCRD's Expert Group Meeting on Regional and Global Economic Integration Development Planning and Information Technology, where he presented a paper entitled "GIS in Urban Planning and Policy Analysis".

November 12-14: Mike Batty attended the International Symposium on Urban and Zonal Planning for Metropolitan Areas, in Shanghai, organized by the Shanghai Peoples' Municipal Government and the Department of Technical Cooperation for Development

of the United Nations (UNDTCD). Batty presented a paper entitled "Land Use and Transportation Planning for Urban Development Zones".

November 13-15: Uwe Deichmann, Michael Goodchild and Stewart Fotheringham were invited presenter at the Statistics Canada Symposium '91: Spatial Issues in Statistics, in Ottawa. Goodchild gave the keynote address, and Deichmann gave a presentation summarizing the results of Initiative 1. Fotheringham's paper title was "The Modifiable Areal Unit Problem in Multivariate Statistical Analysis".

November 16: Paul Densham presented a paper on Data Sharing (authored by Hugh Calkins) to the Ontario Chapter of URISA, held in the civic offices of Waterloo, Ontario.

November 21: William Mackaness presented "Conservation of Spatial Character during Generalization in Map Design, University of Maine, Orono.

November 27: Stewart Fotheringham was funded to visit the University of Waterloo, and presented an invited talk entitled, "The Zone Definition Problem Revisited: Implications for GIS and Spatial Analysis".

November: Karen Kemp gave a GIS education workshop at the Third Latin American Conference on GIS in Chile, and participated in a session on GIS in secondary and higher education at the Association for Geographic Information annual conference in Birmingham, UK. She also presented a workshop on Intelligent Tutorial Systems in Geography in Montpellier, France. In Geneva she visited UNITAR to discuss promoting GIS education in developing countries. She also visited ESRI Espana in Madrid to discuss a Spanish translation of the Core Curriculum for distribution to all Spanish speaking countries.

December 2-4: David Tyler attended the Montana GIS Conference, Bozeman, MT, and presented a workshop on "Global Positioning System (GPS) and GIS."

December 3-4: Michael Goodchild and Karen Kemp presented a short course on GIS at FORMEZ, Naples, Italy.

December: Frank Davis presented "Gap analysis of biodiversity in California" at the California Interagency Wildlife Habitat Task Force, Sacramento; "Estimating regional leaf area index and biomass using multitemporal ground and satellite data" (with M. Friedl) at the Fall meeting of the American Geophysical Union, San Francisco and "A hierarchical method for stratifying land surfaces utilizing satellite and ground-based data" at the same meeting.

December 5: Michael Goodchild made a presentation at a conference on census statistics in Turin, Italy, and gave a seminar in the Department of Sociology, University of Milan.

December 16-17: David Tyler attended the American Society of Agricultural Engineers Symposium on Automated Agriculture for the 21st Century, Chicago, IL, and presented a tutorial on "Contemporary Positioning Technologies".

APPENDIX 3 - VISITORS TO NCGIA SITES

Rod Allan, Royal Melbourne Institute of Technology
 Sven Aber, KM Sweden
 Michael Alspaugh, Senior Planner, Erie County
 Alex Anas, Northwestern University
 Nils Thore Andersson, Malmo, Sweden
 Marc Armstrong, University of Iowa
 William Aymard, EPA/EMSL, Las Vegas
 Bijan Azad, Boston Redevelopment Authority
 Ken Baba, Hitachi
 Robert Baker, University of New South Wales
 Doug Banting, Ryerson Polytechnical Institute, Toronto
 Mateus Batistella, Brazilian Agency for Agricultural Research
 Don Benninghoven, League of California Cities
 Jack Bielman, Lancaster, NY
 Mike Boismenu, Engineering Standards Group, Niagara Mohawk
 David Boyce, Hitachi
 Ian Bracken, University of Wales, Cardiff
 Gilberto Camara, IBM and INPE, Brazil
 Guifa Cao, Chinese Academy of Sciences, PRC
 Ricardo Cartaxo, INPE Brazil
 Marco Casanova, IBM Brazil
 Wilhelm Caspary, Institut fur Geodasie, Germany
 William Clark, UCLA
 Eliseo Clementini, University of l'Aquila, Italy
 Reid Coleman, University of Wisconsin
 Hal Conklin, League of California Cities
 Leslie Curry, University of Toronto
 Dick Croad, Erie County Water Authority
 Joseph DePinto, New York State Center for Hazardous Waste Treatment
 Luiz Dias, INPE Brazil
 Harry Dimitriou, University of Hong Kong
 Wes Dust, Erie County Water Authority
 Manfred Ehlers, ITC, Netherlands
 Javier Espiogo, University of Madrid
 Bill Euler, Tecom Corp
 Innocent Ezigbalike, University of Melbourne
 Nick Faust, Georgia Tech
 Robin Flowerdew, Lancaster University, UK
 Reinhold Friebertshauser, University School, Chagrin Falls, OH
 Steve Garner, EPA/EMSL, Las Vegas
 Len Gaydos, USGS
 Alexander Gennadiyev, Moscow State University
 Ira Gershkoff, United Airlines
 Dennis Gier, San Luis Obispo
 John Gogniat, SUN Microsystems
 Chris Gold, Laval University
 Terry Harmon, Faculty of the University School, Chagrin Falls, OH
 Britton Harris, University of Pennsylvania
 Francis Harvey, Swiss Federal Office of Statistics
 Robert Hausman, IBM
 Bill Hazelton, University of Melbourne
 Eric Heikkila, University of Southern California
 Olaf Hellwich, University of New Brunswick
 Gary Herring, US Postal Service
 Inger Marie Holm-Olsen, Tromso Museum and University of Tromso
 John Houghton, ARCO
 Deh I Hsiung, NSF

Xan Huang, Chinese Academy of Sciences
Takeshi Inouye, Mitsubishi Electric Corporation
Dave James, Lockheed/EMSCO
Erland Jungert, Swedish Defense Research Establishment
Steve Kessel, Curtin University, Perth, Australia
John Kick, New York State Soil Conservation Service
Kim Myung Jin, Ministry of Environment, Seoul
Dick Klosterman, University of Akron
Satomi Kobayashi, Hitachi
George Lakoff, University of California, Berkeley
Rob Lambert, US Army Engineer Topographic Laboratories
Robert Laurini, Université de Lyon, France
Yee Leung, Chinese University of Hong Kong
George Lienkaemper, Forestry Sciences Laboratory
Staffan Lillienberg, KM Sweden
I Kuan Lin, Pacific Gas and Electric
Jim Llinas, CALSPAN
Paul Longley, University of Wales at Cardiff
Guonian Lu, Chinese Academy of Sciences
Bruce MacDougall, University of Massachusetts
Bob Maher, ESRI
Yasuo Matsuda, Hitachi
Ted May, Erie County Water Authority
James McGrady, IBM
Matthew McGranaghan, University of Hawaii
Robert McMaster, University of Minnesota
Andrus Meiner, Estonia
Robert Melter, Long Island University
Bill Miller, ESRI
Beth Moore, Lockheed/EMSCO
Warren Moran, University of Auckland
Jean-Claude Muller, ITC, Netherlands
Joyce Mussey, Defense Mapping Agency
Henry Nowak, US House of Representatives
David Nutter, Intergraph Corp
Tim Nyerges, University of Washington
Michael Osterhold, State Surveying Office, Marburg, Germany
John Pipkin, SUNY at Albany
Rolf Porter, Erie County Water Authority
James Press, University of California, Riverside
Bruce Ralston, University of Tennessee
Carmen Reyes, El Colegio de Mexico
Malcolm Robertson, University of the West Indies.
Clive Ruggles, University of Leicester
Ralph Rumer, New York State Center for Hazardous Waste Treatment
Gerard Rushton, San Diego State University
Eijtan Salingo, Tel Aviv
Burkhard Schaffrin, Ohio State University
Ulf Henning Schauser, University of Kiel
Richard Seekins, Niagara County
Dongjo Seo, Korea Institute of Science and Technology
Chris Shove, University of Oklahoma
Andrew Skidmore, University of New South Wales
Kevin Smith, Culver City Fire Department
Bill Souza, EPA/EMSL, Las Vegas
Yuzo Suga, Hiroshima Institute of Technology
Ed Sullivan, California Polytechnic University
Mike Summers, CALSPAN
Hyo Hyun Sung, Ewha Women's University, Korea
Luiz Tucherman, IBM Brazil
Tom Van Sant, Geosphere Project

Robbie Voigt, California Institute of Technology
Stewart Volkow, Intellimation
Paul Waddell, University of Texas at Dallas
James Weatherington, US Postal Service
Chris Webster, University of Wales College of Cardiff
Eric Weiner, IBM
Jim Welsh, SUNY at Albany
Bob Wilkinson, Central European University
Jerry Williams, IBM
David Wong, University of Connecticut
Peets Woolfaardt, Rand Afrikaans University, Johannesburg
Jin Zhang, Chinese Academy of Sciences

APPENDIX 4 - COURSES TAUGHT BY NCGIA FACULTY

1. Santa Barbara

Remote Sensing Techniques, Winter 1991; Hajic

Production Cartography, Winter 1991; Lanter

Special Topics in Cartography, Winter 1991; Tobler

Techniques of Geographic Data Analysis, Winter 1991; Michaelsen

Technical Issues in GIS, Winter 1991; Smith

Location Theory in Geography, Winter 1991; Church

Scientific Reasoning in Geography, Winter 1991; Couclelis

Seminar in Cartography, Winter 1991; Tobler

Intermediate Geographic Remote Sensing Techniques, Spring 1991; Mertes

History of Cartography, Spring 1991; Tobler

Techniques in Geographic Data Analysis, Spring 1991; Anselin

Application Issues in GIS, Spring 1991; Goodchild

Seminar in GIS, Spring 1991; Smith

Advanced Techniques in Geographic Data Analysis, Spring 1991; Anselin

Cartographic Programming, Spring 1991; Lanter

Geographic Photo Interpretation, Fall 1991; Star

Introduction to Cartography, Fall 1991; Lanter

Cartographic Transformations, Fall 1991; Tobler

Introduction to GIS, Fall 1991; Lanter

Seminar in GIS, Fall 1991; Anselin, Davis

2. Maine

Cadastral Systems (SVE 321), Spring 1991; Beard.

Selected Studies in Surveying Engineering - GIS Applications (SVE 498-01), Spring 1991; Beard.

Selected Topics (SVE 698-01), Spring 1991; Beard.

Selected Topics (SVE 698-03), Spring 1991; Frank.

Selected Topics - Research Issues in Object-Oriented Databases (SVE 698-02), Spring 1991; Frank, Egenhofer and Kuhn.

Geometry and Computer Graphics (SVE 452), Spring 1991; Kuhn.

Selected Topics (SVE 698-09), Spring 1991; McGranaghan.

Land Development Design (SVE 425), Spring 1991; Onsrud.

Selected Studies in Surveying Engineering - Land Information Systems in Developing Countries (SVE 598-01), Spring 1991; Onsrud, Beard and Frank.

Selected Topics (698-07), Spring 1991, Onsrud.

Introduction to Surveying (SVE 101), Fall 1991; Tyler.

Plane Surveying (SVE 111), Fall 1991; Tyler.

Introduction to Geographic Information Systems (SVE 271), Fall 1991; Beard.

Remote Sensing (SVE 433), Fall 1991; Tyler.

Engineering Databases and Information Systems (SVE 451), Fall 1991; Egenhofer.

Graduate Seminar (SVE 693), Fall 1991; Tyler.

Selected Topics - Spatial Reasoning (SVE 698-03), Fall 1991; Egenhofer and Frank.

Selected Studies in Surveying Engineering - Development of Casco Bay GIS (SVE 498-01), Fall 1991; Beard.

Selected Studies in Surveying Engineering - Construction Applications (SVE 498-04), Fall 1991; Tyler.

Field Practice (SVE 394), Fall 1991; Tyler.

Selected Studies in Surveying Engineering - Municipal GIS (SVE 498-05), Fall 1991; Beard.

Selected Topics - Development of Casco Bay GIS (SVE 698-01), Fall 1991; Beard.

Selected Topics - Map Generation Prototype Design (SVE 698-02), Fall 1991; Beard.

Selected Studies in Surveying Engineering - Computer Law (SVE 598-01), Fall 1991; Onsrud.

Selected Topics - GIS Case Studies (SVE 698-07), Fall 1991; Onsrud.

3. Buffalo

Advanced Topics in GIS, Spring 1991; Calkins

Cartographic Design, Spring 1991; Buttenfield

Geography of Economic Systems, Spring 1991; Densham

GIS Algorithms and Data Structures, Spring 1991; Mark

GIS Applications, Spring 1991; Calkins

Introduction to Cartography, Spring 1991; Battenfield

Locational Analysis, Spring 1991; Densham

Maps and Mapping, Spring 1991; Mark

Multivariate Statistics in Geography, Spring 1991; Fotheringham

Regional Population Analysis, Spring 1991; Rogerson

Population Geography, Spring 1991; Rogerson

Transportation Systems, Spring 1991; Batty

Advanced Land Use Analysis, Fall 1991; Batty

Cartographic Internship, Fall 1991; Battenfield

Computer Cartography, Fall 1991; Battenfield

Geographic Perspective and World Issues, Fall 1991; Calkins

Introduction to GIS (undergraduate), Fall 1991; Densham

Introduction to GIS (graduate), Fall 1991; Calkins

Map and Mapping, Fall 1991; Battenfield

Regional Analysis, Fall 1991; Rogerson

Spatial Decision Support Systems, Fall 1991; Densham

Univariate Statistics in Geography, Fall 1991; Fotheringham, Rogerson

Urban Geography Models, Fall 1991; Fotheringham

APPENDIX 5 - GRADUATE DEGREES GRANTED AT NCGIA SITES

1. Santa Barbara

Ralph Dubayah, PhD, Winter 1991, "The Topographic Variability of Solar Radiation" (Dozier, Davis, Simonett, T. Smith).

David Woo, PhD, Winter 1991, "A Feasibility Study of Using Landsat MSS Data to Map Tropical Rice Fields in Ifugao, Philippines" (Estes, Simonett, Davis, R. Morris).

David Stoms, PhD, Fall 1991, "Mapping and Monitoring Regional Patterns of Species Richness from Geographic Information" (Estes, Davis, Goodchild, Scott).

Leonard Gaydos, PhD, Fall 1991, "Scale Dependent Measurement of Vegetation in Urban Areas" (Estes, Goodchild, Davis, Rowntree).

Howard Veregin, PhD, Fall 1991, "The Role of Uncertainty in Nuclear Winter Modeling" (Couclelis, Goodchild, Lanter, Eardley).

Xiao Li Yang, MA, Winter 1991, "Design and Implementation of a Spatial Data Base for a Blind and Visually Impaired Navigational System Using GIS: Components of a Visual Guidance System" (Golledge, Goodchild, Couclelis).

Brean Duncan, MA, Spring 1991, "Utilizing GIS Technology to Combine Regional Physiognomic and Floristic Vegetation Maps" (Davis, Estes, Goodchild).

Aaron Moody, MA, Spring 1991, "Spatial Variability of Soil Properties Beneath Quercus Agrifolia on Santa Cruz Island, California" (Jones, Michaelsen, Davis).

2. Maine

Dilwyn Knott, MSc (Surveying Engineering), December 1991, "Legal Rationale Supporting Common Rules of Construction Used by Land Surveyors" (Onsrud, Hintz, Tyler, Hermansen)

Bingcai Zhang, MEng (Surveying Engineering), December 1991.

Malcolm Fuller, MSc (Surveying Engineering), August 1991, "Development of an Automated Image Registration System for Digital Images using Interest Operators" (Ehlers, Hintz, Sader).

Ian Greasley, MSc (Surveying Engineering), December 1990, "Partially Ordered Sets and Lattices: Correct Models of Spatial Relations for Land Information Systems" (Frank, Egenhofer, Franzosa, Beard, Herring).

Gary Jeffress, PhD (Surveying Engineering), November 91, "Land Ownership Information Use in Real Property Market Transactions" (Onsrud, Beard, Duchesneau, Hintz, Tyler).

Rowland Sidjabat, MEng (Surveying Engineering), August 1991.

David Steiner, MSc (Surveying Engineering), August 1991, "Digital Orthophotography for Integration with Geographic Information Systems" (Ehlers, Beard, Hintz, Tyler).

Jeffrey Wood, MSc (Surveying Engineering), August 1991, "The Development of a Landslide Database for Westbrook, ME" (Beard, Hintz, Tyler).

Raju Chithambaram, MSc (Surveying Engineering), December 1990, "Polygon Skeleton: A Generalization Tool" (Beard, Barrera, Tyler).

3. Buffalo

Andrew Curtis, MA, Summer 1991, "An Investigation into the Hierarchical Processing of Spatial Information by Using the Competing Destination Model" (Fotheringham).

Frank Fico, MA, Fall 1991, "Generalization of the Digital Chart of the World" (Buttenfield, Mark).

Scott Freundsuh, PhD, Fall 1991, "Spatial Knowledge Acquisition: Human Navigation and Wayfinding" (Mark, Calkins, Densham, and Bob Lloyd [University of South Carolina]).

Tom Kress, MA, Fall 1991, "Visualization of Spatial Data Quality" (Buttenfield, Mark).

Hui Lin, PhD, Fall 1991, "Reasoning and Modeling of Spatio-Temporal Intersection" (Calkins, Mark, Densham, Andrew Frank).

John M. McAvoy, MA, Spring 1991, "Algorithms for the Conversion of Contour Lines to Triangulated Irregular Networks" (Mark, Calkins).

Michael Mulligan, MA, Fall 1991, "User Interfaces: Some Issues for Larger Spatial Data Handling Organizations" (Mark, Calkins).