NATIONAL CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS

ANNUAL REPORT

Year 5
(December 1, 1992 - November 30, 1993)

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

April 26, 1994

NATIONAL CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS

ANNUAL REPORT

Year 5
(December 1, 1992 - November 30, 1993)

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 under a five year cooperative agreement with the Regents of the University of California. 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 fifth full year of operation. The life cycles of two Center research initiatives came to an end with the acceptance of their closing reports by the Board of Directors: Use and Value of Geographic Information (I4, begun in May, 1989), and Design and Implementation of Large Spatial Databases (I5, begun in July 1989). New initiatives were begun on Formalizing Cartographic Knowledge (I8, specialist meeting in October, 1993) and Spatio-Temporal Reasoning in GIS (I10, specialist meeting in May, 1993). The Secondary Education Program continued its objective of promoting the introduction of GIS and GIA into the high school curriculum, and workshops were held for teachers at Santa Barbara and Maine. The Center organized the Second International Conference/Workshop on Integrating GIS and Environmental Modeling, in Breckenridge, CO in September, 1993, with over 600 attendees. A small conference on GIS and Society was held in November in Friday Harbor, WA, with the objective of exploring the social implications of the widespread adoption of GIS technology.

During Year 5 the process of renewing the Center's cooperative agreement with the National Science Foundation was brought closer to conclusion. The renewal will provide funding at an increased level through November, 1996.

1. BACKGROUND

1.1 Center mission

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 fifth year's operation began officially on December 1, 1992. 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.

In response to continuing trends in the field of geographic information and analysis, and to prepare for an extended process of evaluation by NSF in connection with possible renewal of the Center's cooperative agreement beyond 1993, a strategic planning exercise was conducted in 1991. It led to the adoption of a new mission statement, and new goals and objectives, and these became the basis for a renewal proposal submitted in November, 1991, and covering the period 12/1/93 through 11/30/96. 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.

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.

The consortium's successful 1988 proposal to NSF laid out a comprehensive research agenda for research in geographic information and analysis, aimed at removing what were seen as impediments to the effective use of GIS technology. The agenda was subsequently published in the *International Journal of Geographical Information Systems* [3(2): 117-136 (1989)]. In 1991 the agenda was rewritten, in conjunction with the strategic planning exercise and the renewal proposal, to reflect better the evolution of the field and the contributions made by research both inside and outside the Center in the previous three years. It is available as *NCGIA Technical Report 92-7*.

In June, 1992, the Center adopted a new, revised research plan that preserved the research initiative as the primary vehicle for organizing work on the research agenda, but with the addition of new vehicles, a more rigorous process of review of proposed initiatives, and more formal mechanisms for collaboration with individuals or groups outside the Center. Full details of the research plan that now guides the research operations of the Center can be found in the Annual Report for Year 4, and are also available from any of the Center sites. Announcements summarizing opportunities for collaboration with the Center, through the Visiting Fellowships Program, Collaborative Grants Program, or through proposals for new research initiatives, appear regularly in the Center newsletter, *UPDATE*, and in other publications.

1.2 The broad context of NCGIA in 1993

When the competition for the Center was announced by the National Science Foundation in 1987, funding for the Center was to last five years, with a possible extension for a further three, based on a review at the end of the third year. The process that began in November 1991 with the submission of the Center's renewal proposal, and led to a site visit by an NSF review team in June 1992, finally ended successfully in February, 1994, with the signing of a cooperative agreement between NSF and the University of California, Santa Barbara, renewing the Center's NSF funding through November 1996. Although the renewal process lasted more than two years, the broad terms of the agreement were known late in 1992, allowing the Center to put in place new programs and procedures in advance of the formal renewal. NCGIA is very excited about what these new programs mean for new areas of Center research, and new activities in education and outreach.

One of NSF's most frequently expressed concerns during the review process was over the extent to which the Center functions as a truly national resource. As a result, the renewal includes funding for two new programs. One is the Visiting Scholars Program, which is designed to open the three NCGIA sites to visitors from elsewhere in the national research community, for extended periods of time. The other is the Collaborative Grants Program, to encourage collaborative projects between NCGIA and other research groups within the U.S. NCGIA would like to extend a warm invitation to anyone interested in research in geographic information and analysis to find out more about these programs, and think about participating in them.

Year 5 saw a series of exciting developments at the national level. The National Research Council's Mapping Science Committee, whose current membership includes two Center researchers (Michael Goodchild, Santa Barbara, and Barbara Buttenfield, Buffalo) published its report *Towards a Coordinated Spatial Data Infrastructure for the Nation*. The report, one in a continuing series of NRC reports on issues of national concern in GIS and GIA, defines a National Spatial Data Infrastructure (NSDI) and calls for partnerships between all levels of government and the private sector to build it. NSDI is defined by the Mapping Science Committee as "the means to assemble geographic information that describes the arrangement and attributes of features and phenomena on the Earth. The infrastructure includes the materials, technology, and people

necessary to acquire, process, store, and distribute such information to meet a wide variety of needs" (NRC, 1993). The Gore Commission's report *Reinventing Government* committed the Administration to building the NSDI. The Office of Management and Budget strengthened the mandate of the Federal Geographic Data Committee as the coordinating agency for NSDI in the federal government, and the Secretary of the Interior, Bruce Babbitt, took over the Chair. Within the academic sector, NCGIA was authorized by its Board of Directors to explore the establishment of a university consortium, to help build the research and education infrastructure for NSDI and to develop a unified voice within the academic community across all of the disciplines involved in geographic information science. Open meetings were held at several conferences, most recently at GIS/LIS in Minneapolis in November, 1993, and moves are now under way to hold a founding meeting late in 1994. All of these developments suggest a robust and exciting future for geographic information, and much attention will be devoted over the next months to determining NCGIA's role in it.

Before NSDI can materialize in anything close to the form envisioned in the NRC report, there will have to be research on several key problems that currently lack clear solutions, as well as substantial investment in education, particularly in K-12 and the community colleges, where new geographic technologies have had very limited exposure up to now, with some very notable exceptions. Unfortunately there is a widespread view that the creation of maps and geographic data in general is a straightforward process, well understood and with little need for further research and development. It is widely believed that the world, and the U.S. in particular, are well mapped, and that high quality base mapping is readily available at useful scales. The prevailing view is that GIS are simply containers of maps, and therefore present no special problems. Of course none of these assumptions are true, but the Center and other proponents of research and education in GIS and GIA will have to work hard to convince governments and taxpayers that the NSDI is a worthwhile investment that will return its value many times over. To make NSDI work, we will need to find much better ways of describing spatial data, through metadata standards that are based on sound theory. Users of data will need much better ways of learning about data quality, and its implications for their analyses, models, and decisions. It will have to be much easier to transfer data between systems, and for users to understand the data they have received. And we will have to resolve the whole complex of institutional barriers to data sharing - pricing of data, protection of intellectual property and personal privacy, legal liability, and equity of access. All of these are key research issues for NCGIA's and the nation's agendas in the coming years.

In late January, NSF sponsored the first Education-GIS conference in Washington, DC, assembling a group of educators, GIS specialists, and teachers to discuss ways of bringing GIS into the K-12 curriculum. Keynote presentations were made by Michael Goodchild (Santa Barbara) and Barbara Buttenfield (Buffalo), and NCGIA's SEP coordinator, Steve Palladino, helped to organize the conference. Everyone was impressed by the software and data on display, and by what individual teachers have managed to achieve in their own classrooms, often with very limited facilities. Several important lessons emerged - how useful GIS exposure can be to a student growing up in today's world; how its pedagogic value goes well beyond the teaching of geography into the development of problem-solving and other life skills; and how little we know about the ability of GIS to teach basic concepts of space.

These are exciting times for geographic information, and they provide an exciting context as NCGIA moves into Year 6. NCGIA's researchers and staff feel proud of what has been achieved in the first five years of the Center's operation, and look forward to the new opportunities offered by renewal.

REFERENCES

NCGIA (1989) The research plan of the National Center for Geographic Information and Analysis. *International Journal of Geographical Information Systems* **3**(2): 117-136.

NCGIA (1992) *A Research Agenda for Geographic Information and Analysis.* Technical Report 92-7. Santa Barbara, CA: National Center for Geographic Information and Analysis.

NRC (1993) *Toward a Coordinated Spatial Data Infrastructure*. Mapping Science Committee, National Research Council. Washington, DC: National Academy Press.

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 24-36 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 fifth year two initiatives were begun, and two were completed, leaving a total of six active initiatives at the end of year 5:

6. *Spatial Decision Support Systems*. Co-Leaders: Paul J. Densham (Buffalo), Michael F. Goodchild (Santa Barbara). Specialist Meeting: Santa Barbara, March 1990. The initiative's findings were presented at a session at the Association of American Geographers Annual Meeting in Atlanta, GA, in April 1993.

7. *Visualizing the Quality of Spatial Information*. Co-Leaders: M. Kate Beard (Maine), Barbara P. Buttenfield (Buffalo). Specialist Meeting: Maine, June 1991.

8. *Formalizing Cartographic Knowledge*. Leader: Barbara P. Buttenfield (Buffalo). Specialist Meeting: Buffalo, October 1993.

9. *Institutions Sharing Spatial Information*. Co-Leaders: Harlan Onsrud (Maine), Gerard Rushton (University of Iowa). Specialist Meeting: San Diego, February 1992.

10. *Spatio-Temporal Reasoning in GIS*. Co-Leaders: Reginald G. Golledge (Santa Barbara), Max Egenhofer (Maine). Specialist Meeting: Lake Arrowhead, CA, May 1993.

12. *Integration of Remote Sensing and GIS*. Co-Leaders: John E. Estes, Jeffrey L. Star (Santa Barbara). Specialist Meeting: Sioux Falls, December 1990. The initiative's findings were presented at IGARSS in Graz, Austria, in April 1993.

13. *User Interfaces for GIS*. Co-Leaders: David M. Mark (Buffalo), Andrew U. Frank (Maine). Specialist Meeting: Buffalo, June 1991.

14. *Spatial Analysis and GIS*. Co-Leaders: A. Stewart Fotheringham and Peter A. Rogerson (Buffalo). Specialist Meeting: San Diego, April 1992.

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

Initiative 4: Use and Value of Geographic Information (closing report approved and published following June, 1993 Board of Directors meeting). 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.

Initiative 4 was drawn to a close by early summer 1993. Extending from the diffusion of innovations work was a case study research project that set forth a method for testing technology transfer theories in GIS environments. Investigators at other universities were invited to use the process to carry out a single case study to test a sample series of provided falsifiable hypotheses. Bijan Azad (MIT), Zorica Budic and David Godschalk (UNC-Chapel Hill), and Steve Frank and Barbara Bicking (Maine), all pursued use or partial use of the methodology in separate case studies. A background paper, instructions to potential participants, a list of thirty sample technology transfer hypotheses, and papers describing results of the Budic/Godschalk and Frank studies are included in *NCGIA Technical Report 93-8*.

A major research specialist meeting on the "Diffusion of GIS in Europe" was hosted under the European GISData program in October 1993. This meeting extended much of the research carried out by NCGIA Initiative 4 and the NATO workshop. The paper co-authored by U.S. researchers active in survey and case study research under Initiative 4 was presented by Harlan Onsrud at their meeting.

Initiative 5: Very Large Spatial Databases (VLSDB) (closing report approved and published following June, 1993 Board of Directors meeting). Initiative 5 was closed in August, 1992, with presentations at the Fifth International Symposium on Spatial Data Handling in Charleston, SC, and the closing report was approved by the Board of Directors in June, 1993. Although the initiative has closed, research is continuing on key issues at the heart of the initiative, and the International Symposium series on Large Spatial Databases that started in Santa Barbara in 1989 had its third biennial meeting in Singapore in 1993. Other major research projects that are likely to have major implications for this field are now in place, such as the Sequoia 2000 project, and some of the principal researchers involved with these projects have significant ties with NCGIA.

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.

Highlights of research events at Buffalo over the past year include the completion and successful defense of PhD student Yuemin Ding's thesis "Strategies for Parallel Spatial Modeling on MIMD Computers" in April. This research develops strategies for decomposing spatial problems into parallel processes to run on multiple instruction multiple data (MIMD) architecture parallel computers. It was used by Ding and Densham in the development and implementation of a number of parallel algorithms on a Transputer array for generating shortest paths through a network, Delaunay Triangulations and Thiessen Polygons, and hill-shading on digital elevation models. Paul Densham and PhD student Catherine Dibble supplemented this work by investigating the use of Genetic Algorithms to generate interesting alternatives - those which are maximally different in attribute space but perform similarly in objective space. Both of these developments were incorporated in Densham's LADSS (Locational Analysis Decision Support System) software.

Stewart Fotheringham, Paul Densham, and PhD Student Andrew Curtis have continued the research effort into the modifiable areal unit problem and its effects in linked spatial models. Fotheringham, Densham and Curtis's article "The Zone Definition Problem in Location-Allocation Modeling" is awaiting publication, and others are also forthcoming. Research on this topic will continue as part of I14.

Multiple presentations about I6 research were made at the AAG in Atlanta, and at Auto Carto and GIS/LIS in Minneapolis, with articles being included in the latter conference proceedings.

The I6 closure report is to be submitted at the December 1993 Board Meeting, and threads from the I6 research agenda will be picked up by I17, which was approved in principle at the June 1993 Board Meeting.

The third edition of the I6 newsletter was compiled by Bruce Ralston (University of Tennessee) and mailed to all persons on the initiative mailing list.

At Santa Barbara, NCGIA continued its multi-year project in the area of spatial decision support systems with Hitachi America Ltd. Two Hitachi resident researchers are working at Santa Barbara on a continuing basis, and two research assistants are funded by the project, which involves Richard Church, Helen Couclelis, and Michael Goodchild. The project is investigating: 1) optimization of the spatial arrangement of energy production and consumption in urban areas, including fuel cells, heat pumps, and waste treatment plants; and 2) the use of cellular automata and neural networks to model and control urban space-time processes related to energy production and consumption, including urban heat islands and urban growth. Both projects will result in the development of spatial decision support systems for designing "green" cities. A second I6 related project funded by Caltrans (the California State Department of Transportation) is investigating the design and implementation of "navigable" databases for support of spatial decisions on transportation networks, under the direction of Church and Goodchild.

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.

A successful activity relating to I7 topics has been the *Data Quality Visualization Challenge*. The objective of the Challenge was to generate external interest on the problem of visualizing spatial data quality. The challenge was co-sponsored by the U.S. Environmental Protection Agency and the USDA Soil Conservation Service (who each supplied data sets) and by the American Statistical Association. Eight final papers for the Challenge were submitted and sent to a panel of judges for review. The judges included Rick Becker, AT&T; Dennis Lytle, SCS; Phil Ross, EPA, Environmental Statistics Division; Charles Spooner, EPA Chesapeake Bay Program; Waldo Tobler, UCSB; and Leland Wilkinson, Systat. Presentations and awards for Challenge projects were made at GIS/LIS '93 in Minneapolis. The overall winner was the group led by Alan MacEachren, from Pennsylvania State University. The student winner was Bouchra Miri, a former Master's student in Surveying Engineering at the University of Maine. Maine graduate students' papers appearing in GIS/LIS '93 Proceedings included: Steven Frank, "Using Visualization Techniques to examine the Effects of Random Control Points on Grid Interpolation"; Bouchra Miri, "Data Quality: Transformations Across Scales"; Khaled Hassen, "Visualization of Soil Boundaries in a Cell Based Model".

Khaled Hassen and Kate Beard submitted a paper, "Reference Grids: a Technique for Visualizing Process Error" to a refereed journal. This paper reports on reference grids as a visual audit trail to document changes in

spatial data introduced by GIS operations. Hassen is continuing this research for his PhD dissertation. An interesting development has been the visualization of functions, or visualizing the outcome of GIS operations. Assuming a GIS process is some function f(x,y), we have been working on graphic functions g(x,y) which visualize the behavior or outcome of f(x,y). Initial results suggest that piecewise linear transformations mimic the behavior of several geometric GIS processes. The piecewise linear transformation can then be applied to a grid which captures a graphic picture of the result.

Jeff Paradis and Kate Beard have completed a paper on "Data Quality Filter: A Users Tool for Data Quality Assessment" and have submitted it to *URISA Journal*. This paper reports on a technique in which users set parameters for an error budget. Data are filtered based on these parameters and only data which pass the filter are displayed.

William Mackaness and Kate Beard prepared a paper on "Visualization of Interpolation Uncertainty" which was presented at Auto Carto 11. Interpolated values are typically represented as isolines or perhaps Thiessen polygons in the case of areal interpolations. In few if any presentations is the variation in the uncertainty of the predicted values communicated. As reliability of interpolated values depends on factors including: sampling scheme, number of sample points, interpolation method, measurement error in the observed x, y, z values as well as the nature and complexity of the observed phenomena, visual expressions for each of these components provides insights on their contribution to uncertainty. This research examines the behavior of observations and interpolation methods and develops visual techniques which communicate spatial pattern in the uncertainty of predicted values.

Kate Beard and Carl Amrhein, who spent three months at Maine during Summer 1993, have been examining the aggregation or modifiable areal unit problem using radon data for the State of Maine. Radon which has been a suspected contributor to lung cancer has shown no positive correlations with lung cancer rates when aggregated to demographic units for this comparison. Extensive radon measurements within schools allow for testing aggregation effects within schools, within zip codes, town and counties and for comparison of these aggregations against natural aggregations based on soil and geologic units.

Gary Hunter (University of Melbourne) was in residence at Santa Barbara for the first six months of 1993, working on I7 issues. He and Michael Goodchild won the Horwood Prize for their presentation at URISA on "Managing the Uncertainty in Spatial Databases: Putting Theory into Practice", which is also published in *URISA Journal*. A second paper discussing the visualization of the 7m root mean square error (RMSE) of USGS digital elevation models (DEMs) has been accepted by *Photogrammetric Engineering and Remote Sensing*, and a third paper is under review. Also at Santa Barbara, work continues by PhD student Charles Ehlschlaeger on the visualization of DEM error using animation techniques.

At Buffalo, Victor Wu successfully defended his PhD dissertation on "Object-Based Queries for Spatial Data Quality". Barbara Buttenfield chaired his PhD committee. Wu and Barbara Buttenfield have an article forthcoming in the journal *Computers, Environment and Urban Systems* on "Spatial Data Quality and its Evaluation", extending the conceptual framework first proposed by Beard and Buttenfield in a presentation made at the IEEE Conference on Visualization in College Station, TX, in 1992. The journal paper incorporates Searle's speech acts into the data qualtiy framework, and applies it using implementations suggested by Winograd and Flores. Barbara Buttenfield was guest editor for a special issue of the international journal *Cartographica* on "Mapping Data Quality", which appeared in the Summer/Autumn issue of 1993, and included I7 papers by Barbara Buttenfield, Matthew McGranaghan (University of Hawaii, and University of Maine), Peter Fisher (University of Leicester), Mark Monmonier (Syracuse University), and Kate Beard and William Mackaness (Maine). Barbara Buttenfield extended and refined the SDTS Browser, an online hypertext tutorial based on the Data Quality section of the Spatial Data Transfer Standard (Federal Information Processing Standard 173), running on the Macintosh. The tutoral contains full hypertext links and demonstrates the complexity of defining data quality components. The Browser was demonstrated in

September, 1993, at USGS in Reston, VA, and at the NCGIA Second International Conference/Workshop on Integrating GIS and Environmental Modeling in Breckenridge, CO, in the same month.

Initiative 8: Formalizing Cartographic Knowledge (began October, 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 U.S. 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.

I8 builds on results from I3 (map generalization and issues of scale and resolution) and I7 (visualization issues), and also draws on (and contributes to) I13 (interface for the prototype) and I6 (use of graphics for spatial decision support). The initiative focuses 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 I8 Specialist Meeting was held in Buffalo from October 24-27, with over 20 participants from a dozen different countries representing academic, private sector, and national mapping agency viewpoints. Professor Jan Bjorke of the University of Trondheim, Norway, visited Buffalo during September and October to pursue research on map generalization, and Michel Rheault, Laval University, Quebec visited the Center in October to learn about Center activities related to knowledge acquisition and cartographic design. Both visitors attended the NCGIA Specialist Meeting. Wojtek Chelmicki from Jagiellonian University, Poland also attended the Specialist Meeting as part of his semester in residence at SUNY Buffalo's Geography Department to learn more about GIS. William Mackaness and Michael Collins from the University of Maine participated in the Initiative and chaired sessions at the meeting.

At the specialist meeting, four topics were identified as having high priority for research: formalizing cartographic language, evaluating cartographic design, implementing data models to support cartographic knowledge representation, and identifying new or novel methods for eliciting cartographic knowledge.

A panel session was held at GIS/LIS in Minneapolis in November to disseminate a preliminary research agenda and to initiate discussion in the community on research related to cartographic knowledge representation. Panelists included some I8 Steering Committee Members: Barbara Buttenfield (Chair); Geoff Dutton, Harvard Design and Mapping; Peter Fisher, University of Leicester;
Roberta Lenczowski, Defense Mapping Agency; and Robert Weibel, University of Zurich.

William Mackaness has authored a paper jointly with Andrew Turk from Murdoch University, Australia entitled "The Cognitive Ergonomics of Computer-Assisted Visualization Design". The paper acknowledges the need for the user to be integrated in the design process but this in turn raises the issue of how to optimize the interaction between human and machine and with respect to the design process, to formalize the definition of a "good map". Michael Collins has written a paper with William Mackaness entitled: "On the Abstraction of Cartographic Objects from Remotely Sensed Imagery" which looks at the support role played by remotely sensed imagery in cartometric analysis and data abstraction for cartographic representation as well as the maintenance of currency in visualizations and databases. The authors are in the process of submitting revised versions of their papers to journals.

At Buffalo, Michael Leitner completed his Master's thesis project "Multi-Scale Inventory of a Topographic Map Series" in March 1993. This work continues an ongoing project at Buffalo to inventory symbol changes on European topographic map series. On October 28, Chris Weber defended his dissertation "Sonic Enhancement of Map Information: Experiments Using Harmonic Intervals" to a committee of Barbara Buttenfield (chair), David Mark, Paul Densham, and Michael Wright of the State University College at Buffalo. This is an example of empirical research to elicit formal measures of knowledge that may enhance thematic map data. Additionally, Paul Schwartz completed his Master's thesis "Digital Typography in Cartographic Design" as part of the research funded by the World University Games project at Buffalo, supervised by Barbara Buttenfield.

Barbara Buttenfield spent the first half of her sabbatical year at USGS National Mapping Division in Reston, VA, working on I8 related research. She has begun a project to extend the DLG-E data model to integrate object representations for multiple scales. Preliminary findings will be presented at the December 1993 European Science Foundation meeting on data generalization in France. As part of her sabbatical activities with USGS, Barbara Buttenfield has also completed a needs and requirements study at the Library of Congress Geography and Map Division in Washington, DC, to advise them on automating their map cataloging and bibliographic research operations.

Initiative 9: Institutions Sharing Geographic Information (begun February 1992). Geographic information is used to address a broad range of critical problems, and thus the value and social utility of geographic information comes from its use. Sharing of geographic information is important because the more it is shared, the more it is used, and the greater becomes society's ability to evaluate and address the wide range of pressing problems to which such information may be applied. Thus, the demand for efficient, equitable, and timely access to spatial data by the user community will continue to grow. As the need to share grows, there will be a greater need to understand the patterns of institutional, organizational, and individual behavior within the GIS user community. Prospective models and prescriptive strategies for sharing spatial data from the local level to global scales need to be developed. The goal of this initiative is to expand the knowledge base of institutional, organizational, and behavioral issues which will allow development of such models and strategies.

This initiative was organized by a seven member core planning group representing six universities and is led by Harlan Onsrud (University of Maine) and Gerard Rushton (Iowa). The Initiative 9 specialist meeting was held February 26-29, 1992, in San Diego, and focused primarily on behavioral and organizational issues acting as impediments or incentives to the sharing of geographic information among and within organizations. The results of the Specialist Meeting are documented in *NCGIA Technical Paper 92-5*.

Sharing Geographic Information consists of twenty-nine chapters prepared by authors who participated in the I9 specialist meeting. The book has been in the hands of the publisher, The Center for Urban Policy Research - Rutgers, for quite some time, and should be available shortly.

A session on research related to I9 was held at GIS/LIS' 93 in Minneapolis in November. Ongoing progress reports on GIS survey and case study work relating to sharing issues were presented by Richard Weatherbe from Buffalo, Earl Epstein from The Ohio State University, Steven Ventura from the University of Wisconsin, and Bijan Azad from MIT. Several co-authors of the papers were also present and the session was well received.

NCGIA is collaborating with the University of Wisconsin and Ohio State University in research on the sharing of land data, and diffusion of GIS technology, in study areas in the states of Wisconsin and Ohio. Presentations on this work were made at the URISA conference in Atlanta in July, 1993.

Harlan Onsrud traveled to the first European Science Foundation GISDATA Specialist Meeting which was held in Knutsford, England, October 27-31, 1993. He presented a paper co-authored by fourteen U.S. researchers, "Experiences in Acquisition, Implementation, and Use of GIS in U.S. Local Governments: A Sampler of Academic Studies and Findings." The paper is likely to be published as a chapter in an upcoming book on the Diffusion of GIS in Local Government in Europe.

NCGIA has begun a one year program of work with USGS to identify datasets to form the backbone of the National Spatial Data Infrastructure. Specifically, the project is establishing criteria for identifying high priority framework data sets for NSDI, defining minimum technical specifications that must be met by these data sets, including content and positional accuracy, and initiating further discussion of these criteria and specifications. The work includes convening a "focus group" of experts in a wide range of areas of application of spatial data to identify and refine questions, conducting a survey of a broad sample of spatial data users, and analyzing the results and compiling them into a major report on framework data specifications. Harlan Onsrud and Michael Goodchild are serving as co-PIs.

Harlan Onsrud and Marilyn Lutz, University of Maine Libraries, have submitted a proposal to the U.S. Department of Education to fund a GIS Research Literature Center which would allow on-line full-text retrieval for most GIS conference articles.

Steven Frank, a doctoral student at Maine, has made substantial progress in his investigation of cataloging paradigms for spatial metadata. "Finding Spatial Information in the Information Infrastructure" was submitted to the *International Journal of GIS* and is likely to be published upon incorporation of several of his research findings. "The National Spatial Data Infrastructure: Designing Navigational Strategies" will be published in the *URISA Journal*. "Cataloging Digital Geographic Data in the Information Infrastructure: A Literature and Technology Review" has been accepted for publication in *Information Processing and Management*. "A Review of Digital Spatial Data Cataloging Systems" is currently under review by *Photogrammetric Engineering and Remote Sensing*.

The development of case study and survey research work has progressed along several fronts. Harlan Onsrud and Jeffrey Pinto (College of Business Administration) are continuing to advance a study and survey instrument to investigate a broad range of institutional effects on sharing across departments. Ben Niemann from the University of Wisconsin is arranging for a series of presentations on I9 topics at URISA '94 in Milwaukee. Work to be reported is likely to be chosen from among the projects being carried out by Bijan Azad, Earl Epstein, Ben Niemann, Jeffrey Pinto, Steven Ventura, and Lyna Wiggins.

Once again the Annual NCGIA GIS Bibliography for the previous year is being planned by Steven Frank and Harlan Onsrud and we expect publication of the third GIS Bibliography in January 1994. The past two bibliographies have been made available by both ftp and in hardcopy (*NCGIA Bibliography Series*) and have received heavy use by the international Internet community.

Lyna Wiggins (Center for Urban Policy Research, Rutgers University) presented a paper co-authored with Bijan Azad (MIT) at the *First Conference on GIS and Applications*, Sharjah, United Arab Emirates, in February 1993. Bijan Azad presented a paper on measurement in research on GIS implementation at the Third International Conference on Computers in Urban Planning and Urban Management in Atlanta during July 1993.

At Buffalo, Hugh Calkins and PhD Student Rick Weatherbe have developed case studies and performed survey research work for I9. During 1993, they visited four sites in order to analyze the spatial data sharing patterns, cost management practices, interagency agreements, public/private sector partnerships, leadership issues and organizational concerns at those sites. In November, Rick Weatherbe presented the paper he co-authored with Hugh Calkins "Case Studies of Spatial Data Sharing", a report of their work, at GIS/LIS '93.

Initiative 10: Spatio-Temporal Reasoning in GIS (began May 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.

Thirty-nine participants attended the Specialist Meeting of this initiative at the UCLA Conference Center at Lake Arrowhead, CA in May 1993. Max Egenhofer (Maine) and Reginald Golledge (Santa Barbara) are co-leaders of this initiative. We received extended abstracts, covering a wide range of different perspectives of the topic (*e.g.*, philosophy, geography, computer science, environmental psychology, planning, linguistics, history, and archaeology). Each paper was refereed by three members of the steering committee (Helen Couclelis, Santa Barbara; Andrew Frank, Technical University Vienna; Stephen Hirtle, University of Pittsburgh; Gail Langran, Intergraph Corporation; David Mark, Buffalo; Daniel Montello, Santa Barbara; and Michael Worboys, University of Keele), who evaluated them for their relevance to the specialist meeting, their scientific quality, and the clarity of the presentation. Steering committee members made recommendations whether or not to invite the author to the meeting. Twenty-two authors were selected for the specialist meeting. The group of participants was completed by some invited discussants, center members, and industrial and governmental representatives.

The two and one-half day meeting was organized as a combination of plenary sessions and working groups (6-7 members). The plenary sessions were organized such that papers covering a similar topic were grouped together into a session, and an invited discussant summarized the major ideas, provided additional and complementary insight, and animated the audience to identify additional challenging questions. These questions formed the basis for the working group discussions, whose tasks it was to identify researchable questions at the granularity of a master's or PhD thesis topic. Results about the working groups were reported in the evening sessions after dinner. On the last day, a small group was charged to organize the detailed questions into a framework. From the working groups, over 80 researchable questions were collected. Participants identified the following framework as representing the research needs:

- Studies of how humans think about geographic space and time, and the formalization of these processes.
- Investigations of how to interact with and display spatio-temporal information.
- Design of efficient methods to store space-time information.

Within each category, a number of topical groups have been determined. We are currently organizing the researchable questions within this framework. Participants will then assign priorities to the questions and topical groups in a vote on e-mail. The prioritized research agenda will be published as an *NCGIA Technical Report*.

Approximately twenty of the Il0 authors have agreed to revise their paper and prepare it for publication. At this stage the most probable publisher looks to be Elsevier, but several others have indicated an interest and

are currently reviewing the outline. We are anticipating receiving revised copies of all manuscripts by the end of November and submitting the final papers, after peer review, by mid-to-late winter quarter 1994.

Since the Specialist Meeting, there has been active research at all three sites on I10 topics, and continued cooperation with outside participants. Two I10-related Special Sessions at the 1994 AAG, March 29-April 2, 1994 in San Francisco, have been organized by Scott Freundschuh (Maine) and Dan Montello (Santa Barbara) on "Sources of Spatial Knowledge and Resulting Cognitive Representations." These sessions have served as outreach to researchers in psychology/cognitive science. Another Special Session titled "Cognitive Cartography" focusing on recent cognitive research in cartography by graduate students in the Departments of Geography at Pennsylvania State University and the University of South Carolina has also been organized by Freundschuh. A third session is organized by Golledge and Egenhofer. A selection of participants from the I10 meetings at Lake Arrowhead will constitute a significant proportion of both sessions, but they will be complemented by additional researchers from geography and psychology in particular. The sessions were designed with the aim of providing follow-up opportunities for I10 participants to expand on their I10 statements and to develop opportunities for interactive cross-disciplinary research.

Also as a follow-up to I10, Professor Steven Hirtle (University of Pittsburgh) will be joining Max Egenhofer to work during summer 1994 at the University of Maine on an I10-related proposal on "Geometries for Spatio-Temporal Reasoning."

During the summer, Egenhofer was invited to the University of L'Aquila, Italy, to work with Italian researchers Eliseo Clementini and Paolino di Felice on problems of hierarchical spatial reasoning in multiple topological representations. A first paper has been accepted for the *International Journal of Geographical Information Systems*, and a second one is being prepared for Spatial Data Handling '95. Clementini visited Maine in September/October to continue this work. Together with Egenhofer and Jayant Sharma, PhD student at Maine, they started a new effort in optimizing spatial queries.

Two other graduate students at Maine are working on I10 related topics: Jung-Hong Hong compares in his PhD dissertation different computational models for reasoning about approximate distances (near, far, *etc.*) and cardinal directions (east, west, *etc.*). His initial results indicate symbolic distance/direction reasoning is stable and independent of an exact numeric representation for approximate distances if the ratio between two successive distance symbols is at least 1:3. For his Master's thesis, Tony Sleezer has started to investigate the interaction with spatio-temporal data in a space/time/process framework. The focus is on geological processes for which he will design a simulation model.

David Mark and Max Egenhofer are continuing their human-subject tests for natural language spatial predicates (*e.g.*, "the road crosses/goes across/goes through the park"). Egenhofer presented a paper on the formalism at Auto-Carto 11.

Scott Freundschuh has been invited by Henry Castner to participate in several sessions on spatial learning and children at the 1994 Joint Canadian Cartographic Association and North American Cartographic Information Society Meeting in August, 1994. While at Maine, Freundschuh has begun research on the effect of color on determining spatial relationships between linear and areal map features with Max Egenhofer and David Mark, and the use of locative (spatial) terms in children's narrative, with Madhu Sharma (Master's student in the Department of Human Development).

A two-day meeting on "Temporal Issues in GIS" was held at the University of Delft immediately prior to and in connection with the 16th ICA meeting in Cologne, May 1-8, 1993. William Mackaness presented a paper entitled "Temporal Events, Episodes, and Evidence - Patterns in Time". Emphasis of the meeting was on discussion of temporal issues including visualization of spatio-temporal space, and concepts, terminology, and issues relating to temporal sampling.

Khaled Al-Taha (LSU), former graduate student at Maine, with Richard Snodgras (University of Arizona), an invited participant at the Pisa conference, and Michael Soo (University of Arizona), compiled a bibliography on Spatio-Temporal Databases. The bibliography has been extensively requested over e-mail by researchers and, due to this extensive interest, will be published in the *International Journal of Geographical Information Systems*.

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.

Two books and a special issue of a journal are being published based on I12 research. Presentations closing the initiative were made at the IGARSS meeting in Graz, Austria, in April 1993. The closing report is in preparation and will likely be submitted to the Board of Directors at its June, 1994 meeting.

Progress on the NCGIA Remote Sensing core curriculum is continuing. Two meetings have been held on the curriculum, funded by the private sector. An editorial about the curriculum was published in *GIS World* and a paper published in the June 1993 issue of *Photogrammetric Engineering and Remote Sensing*. A proposal has been written to NASA to fund the NCGIA Core Curriculum in Remote Sensing, which was recommended as a high priority item in the I12 Specialist Meting. Jeff Star has briefed this proposal, as well as corresponded with several potential sources of funds in the private sector. The steering committee has been kept up-to-date, and we hope to be able to move aggressively in 1994. The *PE&RS* article has prompted a number of individuals to contact us to participate, and we are anxious to begin.

Based on Manfred Ehler's residence at UCSB under I12 funding, Ehlers along with colleagues at Santa Barbara has secured funding from EG&G, Las Vegas, to investigate algorithms for spatial data fusion. Using some poorly known results from a German PhD dissertation from a few years ago, Ehlers has written a new algorithm, and now the collaborators are examining the performance of this algorithm in comparison with several previously well-known algorithms.

The monograph for the initiative, under contact with Cambridge University Press, is well along; drafts of all chapters have been reviewed by Jeff Star and various revisions are underway. We expect to have a manuscript to the publisher for review before the end of 1993, with publication in the third quarter of 1994. Star and Estes will edit the volume. Authors will include Michael Goodchild and Kenneth McGwire (Santa Barbara) on accuracy issues; Terry Smith (Santa Barbara) on large spatial databases; Manfred Ehlers (University of Osnabrüch) on registration; Nick Faust (Georgia Institute of Technology) and Jeff Star (Santa Barbara) on visualization; Gassam Asrar (NASA Headquarters), John Hensen and David Cowen (University of South Carolina) on mapping; and Tim Foresman (University of Maryland, Baltimore County) on management.

The monograph proposal on scale has been submitted to Lewis Press. NASA has approved the draft contract, and we expect to have signatures completed before the end of 1993. Manuscript chapters are to be written during 1994, with publication in mid 1994.

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. The prioritized research agenda for Initiative 13, a report on discussions at the specialist meeting, and the 35 specialist meeting position papers, were published as *NCGIA Technical Paper 92-3*.

I13 progress has continued with Buffalo student Todd Crane's May 1993 completion of his Master's degree project "A Graphical User Interface for Map Production within the Environmental Restoration Program at Los Alamos National Laboratory", a report of work conducted during the summer of 1992. It is expected that Crane will have additional publications based on this research.

Buffalo PhD candidate Michael Gould successfully defended his dissertation, re-titled "Map Use, Spatial Decisions, and Spatial Language in English and Spanish". Gould, currently teaching at the Complutense University in Madrid, will be presenting some results of his research at the European GIS meeting in Paris in March. There are also plans for two or three articles, some of which may be co-authored by David Mark.

The research component of I13 was closed in the late summer of 1993, and it is anticipated that the NATO Advanced Research Workshop (ARW) on "Cognitive Task Analysis for GIS" in March 1994 will serve as the International Conference at the end of the initiative. Tim Nyerges of the University of Washington has received a grant to conduct this workshop, and David Mark, who assisted with the proposal, will serve as Co-Director. The NATO ARW will produce a book.

Initiative 14: GIS and Spatial Analysis (begun 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 focuses 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 specialist meeting for I14 was held April 15-18, 1992, at Humphrey's Half Moon Inn, San Diego. There were 28 academic participants and 9 participants from the government and private sectors. The technical report on the Specialist Meeting is available as *NCGIA Technical Report 92-11*.

Research on the modifiable areal unit problem continues at Buffalo. Stewart Fotheringham and David Wong are preparing a sequel to their paper, published two years ago in *Environment and Planning A*, which will focus on the role of spatial autocorrelation. It is hoped that David Wong will be able to spend a week at Buffalo to complete his research. It is also anticipated that Carl Amrehein will be at Buffalo in the coming year under the auspices of the Visiting Fellows program to work on this topic. Fotheringham organized a special session on the modifiable areal unit problem at the North American Regional Science Meetings in Houston in November.

Other conferences presentations highlighting I14 efforts have included ones on GIS and Spatial Analysis at the Mac/UB graduate conference in Geography in March, 1993, and several at the AAG meetings in Atlanta in April. Additionally, several paper sessions on I14 topics have been organized at the forthcoming AAG '94 conference in San Francisco. A two day conference on GIS and Spatial Analysis, co-sponsored by the NCGIA and the Economic and Social Research Council of the UK, has been planned and will be held in Bristol, UK in April 1994.

Fotheringham and Rogerson have a forthcoming book on GIS and Spatial Analysis (Fotheringham and Rogerson, editors, *GIS and Spatial Analysis*, London: Taylor and Francis) and are editors for a forthcoming special issue of *Geographical Systems*. These publications summarize I14 research results. In addition, Rogerson has been working on the interface between population and analysis and GIS; some of this work will appear in the forthcoming text he co-authored with D. Plane (*The Geographical Analysis of Population: With Applications to Planning and Business.* New York: Wiley).

Michael Goodchild (Santa Barbara) and Paul Densham (Buffalo) participated in an ESRI-sponsored workshop on GIS and spatial analysis at Lancaster University in the UK in June 1993, and made presentations. The meeting provided an opportunity to review several UK efforts to enhance the spatial analytic capabilities of GIS.

At Santa Barbara, Rusty Dodson completed his Master's research on "Integrating GIS and Spatial Analysis: An Implementation and Appraisal of Two Prototype Software Linkages". During the summer of 1993, he and Joel Michaelsen worked on the development of tutorial modules for the linkage of S Plus and ARC/Info which was recently announced by StatSci.

Initiative 15: Multiple Roles for GIS in US Global Change Research (approved in detail, June, 1993). I15 concerns the ways in which GIS could better support regional and global change research. Two major areas in global change studies for which GIS could play an important role are: 1) enhancement of models of Earth system phenomena operating at a variety of spatial and temporal scales across local, regional, and global landscapes, and 2) improvements in the capacity to assess the effects of global change on biophysical (ecological) systems over a range of spatial and temporal scales. For this initiative, we propose a research agenda with five principal objectives. First, this initiative will support the increased integration of GIS and environmental modeling using techniques for managing, manipulating, analyzing, and displaying spatial data. Second, we will critically assess the quality of existing global data in terms of spatially varying accuracy, sampling methodologies, and completeness of coverage and develop means of managing and visually communicating components (*e.g.*, error) of environmental data quality. Our third objective is to develop spatial database techniques that can manager hierarchical structures across multiple scales of spatial patterning. Fourth, we propose to develop methods for dynamically linking human and physical data bases within GIS and for exploring the regional impacts of global change. Finally, alternative means of using GIS for detecting, characterizing, and modeling changes in ecotones will be explored.

Approval in principle for this initiative was given by the Board of Directors at its December 1992 meeting. Approval in detail was given in June 1993.

A preliminary meeting of several potential members of the steering committee was held in Breckenridge, Colorado at the Second International Conference/Workshop on Integrating GIS and Environmental Modeling (September 26-30, 1993) including: Michael Goodchild and Jack Estes (Santa Barbara), Dennis Jelinski (University of Nebraska-Lincoln), David Clark (National Geophysical Data Center, NOAA), Louis Steyaert (U.S. Geological Survey), and Tim Foresman (University of Maryland-Baltimore County).

The Breckenridge meeting, although more broadly based than I15, provided an opportunity to bring together presentations on several key I15 topics. Programs of particular relevance to I15 included a session on hierarchical databases; the keynote presentations by Francis Bretherton (University of Wisconsin) and Roberta Miller (CIESIN); and many sessions on data sources and access. Proceedings of the conference will be published b*y GIS World* in 1994. The Breckenridge meeting also coincided with the publication of the proceedings volume from the Boulder meeting in 1991. *Environmental Modeling with GIS* (Oxford University Press) includes many papers relevant to I15. Goodchild's presentation at Breckenridge focused on the roles played by spatial data in environmental modeling, and on the supply of such data globally, both proposed themes of I15. In July, he and Estes attended a meeting in Nairobi, sponsored by UNEP, on spatial databases for sustainable development and Goodchild made a presentation on issues of accuracy in spatial data. Many other NCGIA researchers participated in the Breckenridge conference, and many made presentations.

Over the past six months since the initiative was approved, research has focused mainly on the development and refinement of specific objectives for I15. In better defining the goals, the co-leaders have received and considered the comments of the Board. Jelinski presented a paper entitled "Multiple Roles for GIS in Global Change Research: Towards a Research Agenda" on the research agenda for I15 at the international symposium "Environmental Information Management and Analysis: Ecosystem to Global Scales" held in Albuquerque, New Mexico, May 20-22, 1993. This paper will be published shortly in an edited volume (Taylor and Francis); the response of the referees was uniformly positive. A paper summarizing the findings of the Breckenridge conference, and coauthored by Michael Goodchild (Santa Barbara) and Louis Steyaert (USGS) will appear in the same volume.

Dennis Jelinski completed a bibliography on ecotones. The focus of this research was to lay the groundwork for analysis of GIS-modeling techniques for measuring dynamic processes characteristic of ecotonal areas where the normal assumptions of homogeneity and uniformity typical of most environmental models are violated. Jelinski is developing a proposal for submission to NSF that will examine by use of a case study the representation of continuous spatial change in ecotones, especially in relation to climate. Jelinski is also preparing a paper on challenges in producing a set of functional requirements and specifications for hierarchical GIS and inference across scales in landscape ecology in view of the modifiable areal unit problem and hierarchy theory.

Initiative 16: Law, Public Policy and Spatial Databases (to begin October 1994). 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.

I16 gained final approval as an NCGIA Initiative at the June Board of Directors Meeting in Buffalo, NY. It will be a new research initiative to begin in 1994, co-led by Harlan Onsrud and Robert Reis (Buffalo). The specialist meeting has been scheduled for October 28-30, 1994, at the Center for the Study of Law, Science and Technology, Tempe, Arizona, and will be held in conjunction with a major conference on the topic of the initiative.

An extensive bibliography divided into the major topics to be addressed by the initiative has been prepared by Harlan Onsrud, Xavier Lopez, and Jeffrey Johnson. The bibliography draws primarily from the law journal and GIS journal literature bases and is being made available both on our ftp site and as an NCGIA publication in the *Technical Report* series. Xavier Lopez and Jeff Johnson at Maine are developing thesis topics and graduate research programs focusing on selected I16 issues.

Initiative 17: Collaborative Spatial Decision Making (to begin 1994). I17 received approval in principle following the June 1993 Board meeting and will be submitted for approval in detail at the December 1993 meeting. The objectives of this proposed initiative are to: (1) examine the body of theory on the design, implementation and use of computer supported cooperative work (CSCW) environments and evaluate their utility for GIS/GIA; (2) identify impediments to the development of highly interactive, group-based spatial modeling and decision-making environments; (3) develop methods for eliciting, capturing and manipulating knowledge bases that support individual and collective development of alternative solutions to spatial problems; (4) develop methods for supporting collaborative spatial decision-making (CSDM), including methods for managing spatial models; and (5) extend capabilities for supporting multicriteria decision-making in interactive, CSDM environments.

Hugh Calkins and PhD student Frank Xia have been actively conducting research in cooperation with the Great Lakes Program at SUNY Buffalo that is relevant to the I17 program. The Great Lakes Program (Joseph DePinto, Director) is a multi-million dollar, multi-year effort focused on: (1) the development and application of toxic chemical exposure models in the Great Lakes; (2) the investigation of human health risks associated with toxic substances in the Great Lakes; (3) the coupling of Geographical Information Systems with water quality models applied to Great Lakes Basin watersheds; and (4) Great Lakes fisheries management. It is on the third aspect of the project, the development of a coupled GIS-watershed contamination modeling framework named GEOWAMS, that Hugh Calkins' and Frank Xia's efforts have been focused.

A Specialists Meeting is tentatively planned to be held in late 1994 in conjunction with the GIS/LIS '94 Meeting in Phoenix.

B. Education

1. General

In education, the major thrust of Year Five has been the continuation of the Center's Secondary Education Project, aimed at exploring the role of GIS and GIA in the secondary school curriculum. In addition, the Center has continued to update and distribute its educational materials for college-level courses, and to provide support for GIS education at all levels.

2. NCGIA Core Curriculum in GIS

The NCGIA Core Curriculum in GIS continues to be in demand. The NCGIA has distributed well over a thousand copies to date. Additional copies of the Core Curriculum have been made available through English language distribution sites in a handful of countries and by newly appearing foreign language editions.

The Core Curriculum appeared for the first time in 1993 in the Hungarian language. The distribution of the Core Curriculum in English began in 1991 through the Technical University of Budapest. Although the Curriculum was well received, the differences in Hungarian educational environments, computer infrastructure, and society at large as well as the language barrier led to an effort to create an adaptation of the Core Curriculum. This adaptation is designed to meet the needs of the Hungarian educational and technical communities. The first volume of the Core Curriculum has been translated into Hungarian and examples contained in the Core Curriculum have been modified to reflect Central European perspectives. This is the first version and is available on diskette. After a year of use in Hungarian universities, colleges, and other institutions, it will be revised and formally published. More information on this resource can be obtained from Dr. Bela Markus, Department of Surveying, Technical University of Budapest, Muegyetem rkp. 3. Kmf. 16, H-1521 Budapest, Hungary.

Also in 1993 Laval University continued its efforts to translate the Core Curriculum into French, under the direction of Prof. Marcel Theriault. The completed French translation will be distributed in France and Belgium as well as Canada, and efforts are under way to distribute it to the French-speaking community in Africa through UN agencies.

3. NCGIA Laboratory Materials Guide Update

Rusty Dodson completed an update of the 1991 Guide to materials for teaching GIS in a computer laboratory environment. The Guide includes full exercises and exercise outlines for GIS activities employing a variety of GIS software commonly used in the teaching laboratory. The Guide also has sections on available data sets for teaching purposes and a list of additional resources useful to this laboratory based instruction. The update is titled *The NCGIA Guide to Laboratory Materials - 1993*. This publication, *NCGIA Technical Report 93-10*, is available from the NCGIA Publications Office.

4. Secondary Education Project

In June, 1993, the Santa Barbara NCGIA site hosted its second successful GIS workshop for pre-collegiate educators. The week of activities included: a GIS short course taught by Mike Goodchild and Steve Palladino; a series of demonstrations of GIS applications and capabilities; hands-on work with a variety of GIS software packages; an ARCVIEW tutorial conducted by Charlie Fitzpatrick, ESRI's K-12 Education Coordinator; discussion on the use of GIS in the classroom; and an IDRISI-based group project utilizing local DEM, land use, and transportation data. The nine workshop participants were representatives of six of the National Geographic Society sponsored Geographic Alliances active now in all 50 states. These teachers returned to

their respective Alliances and schools with a wealth of GIS information that they will communicate through in-service presentations and demonstrations at conferences.

As part of the SEP, the NCGIA site at the University of Maine presented a one week workshop on "GIS in the Secondary Schools" to a group of seven secondary school teachers from June 28-July 2, 1993. Maine's summer workshop attracted teachers primarily from the sciences, in particular, Earth science, as well as computer applications teachers. The workshop was given by Dr. William Mackaness, with assistance from Tony Sleezer, a graduate student in the Department of Surveying Engineering, and Kathleen Hornsby, administrative officer with the NCGIA. Over the five days, the teachers gained an understanding of GIS and how it could be integrated into their curricula. The lectures covered topics including: an introduction to GIS, GIS applications, data sources, data entry and data integration, data models, and future trends in GIS. In addition to the lectures, the teachers were given hands-on exercises to complete, and had the opportunity to view demos provided by graduate students in the Department of Surveying Engineering, as well as a tour of the Image Analysis Laboratory in the Department of Forest Management, and the GIS holdings in Fogler Library. Another major component of the course was that each teacher had to develop a project using GIS using ArcView from ESRI.

The teachers attending the workshops at both sites were able to take part in ESRI's Adopt-a-School program - whereby with the training received in the workshop, each of the schools could apply to receive a "bundle" comprised of ArcView software and data sets on CD-ROM (ArcUSA, ArcWorld, and ArcScene) at no cost to the schools.

Kate Beard, Kathleen Hornsby, and Tony Sleezer conducted a workshop for twelve high school teachers on "Geographic Information Systems for Secondary Schools" at the Integrating Spatial Information Technology: Using Geographic Information Systems in the Planning and Decision-Making Process Conference, South Portland, ME on November 15, 1993. The hands-on workshop introduced educators to ArcView software and how it might be used as a tool in the classroom. William Mackaness was also in attendance.

An outgrowth of the NCGIA GIS workshops for teachers is an *NCGIA Technical Report* (93-2) which describes the workshop offered in 1992 in detail. This Workshop Resource Packet is primarily designed as a resource for institutions with GIS software and expertise that wish to do outreach to their local schools. In addition to the review of the GIS workshop, the report includes a section on GIS use in the schools, outlines of teacher designed GIS projects, a model format of a GIS workshop for teachers, the notes for the GIS short course, a list of GIS and related resources for teachers, and a glossary of basic GIS terminology. As can be seen from this list, the contents of the report may be of interest not only to institutions desiring to do outreach but also to teachers and other individuals.

Another resource for teachers has been developed by the Secondary Education Project. This is a data set on Africa designed to introduce students to digital data as it might appear in a GIS package. The IDRISI Project has kindly agreed to allow the data to be distributed with the data viewing modules of the IDRISI GIS package. This allows students to view in 2D and 3D the various sets of climatic, vegetation, land use, soil condition, and population data drawn primarily from a United Nations Environmental Program study on soil degradation and deforestation. Although very limited in the type of spatial analysis that can be performed, this African Data Viewer (*Technical Report 93-11*) is intended to serve as an entry point activity for teachers and students interested in GIS.

C. Outreach

1. General

The cooperative research effort between NCGIA-Buffalo and the Midlands Regional Research Laboratory (MRRL) was strengthened in April with the signing of a Memorandum of Understanding. The agreement consists of personnel exchange and a cooperative training program. A Memorandum of Understanding for Information Exchange and Training between NCGIA-Buffalo and the United States Fish and Wildlife Service, Lower Great Lakes Fishery Resources Office was drafted, in anticipation that continuing and increased cooperation between the two organizations will continue and be fostered by this agreement. A Memorandum of Understanding between NCGIA-Buffalo and the Library of Congress, Washington DC, was drafted by Barbara Buttenfield.

In anticipation of the NCGIA Visiting Fellows program, which will begin in Year 6, the Buffalo site made contacts with and helped design tentative research programs to be undertaken in cooperation with the following scientists: Dr. Faye Duchin and Dr. Glenn-Marie Lange, Institute for Economic Analysis, New York University to work with Sam Cole and PhD student Frank Xia on the extension of input-output models to the spatially disaggregate domain and to physical inputs and outputs (related to I15); Dr. Joe Ferreira and Dr. Michael Shiffer, Massachusetts Institute of Technology, Dr. Britton Harris, University of Pennsylvania/MIT, Dr. Lyna Wiggins, Rutgers University, and Dr. Marc Armstrong, University of Iowa to work with Mike Batty and Paul Densham on topics related to I17, Collaborative Spatial Decision Making; Dr. Mark Salling, Cleveland State University to work with Hugh Calkins and PhD Student Rick Weatherbe on data and technology sharing (related to I9); and Dr. Carl Amrhein, University of Toronto, to work with Peter Rogerson and Stewart Fotheringham on research in the area of spatial aggregation in the context of geographic information systems (related to I14).

Kate Beard has been invited to join the Editorial Board of the *West Indian Journal of Engineering*, and the Executive Board of the New England Chapter of AM/FM International. She was a member of the 1993 Integrating Spatial Information and Technology (ISIT) Conference Planning committee. The conference was held on November 15, 1993, in Portland, ME.

Max Egenhofer has been invited to join the Editorial Boards of the *International Journal of Geographical Information Systems* and *Cartography and Geographic Information Systems*. In Year 5 he served on the following program committees: Auto-Carto 11, Minneapolis, MN, November 1993; Workshop on Advances in Geographic Information Systems, Washington, DC, November 1993; GIS track of SAC '94 (ACM Conference on Applied Computing), Phoenix, AZ, March 1994; member of the SSD steering committee; co-chair and program committee member of SSD '93; general chair of SSD '95 including organizing the conference in Portland, ME. He also served on the program committee for the European Conference on Spatial Information Theory, Marciana Marina, Italy. With Tony Cohn, Christian Freksa, and Andrew Frank, he organized a workshop on spatial relations.

Jayant Sharma, NCGIA and Surveying Engineering Graduate Research Assistant, visited the National Informatics Centre (NIC), the information systems division of the Planning Commission of the Government of India. He met with two groups, the Urban Mapping and GIS Applications group and the District Information Systems group of NIC (DISNIC), and gave an overview of the NCGIA and a talk on "Geographic Databases: The Issues and some of the Solutions."

In the summer of 1993, Carmelle Cote, a graduate student at Buffalo, worked in Geneva with the UN training agency UNITAR to develop plans for an international network of individuals interested in GIS. This joint NCGIA/UNITAR project will attempt to link experts in GIS, and other resources, with individuals having

very limited exposure to GIS, and very little opportunity to increase that exposure, particularly in the developing countries. It is expected that the project will continue into Year 6.

2. Conferences

Conference on Global Modeling and GIS (December 15-16, 1992). NCGIA-Buffalo sponsored a meeting on Global Modeling and GIS, which was held at the UN Church Center Plaza in New York from December 15-16, 1992. The meeting organizers were Sam Cole and Michael Batty, and a number of experts who could contribute a balance of theoretical, empirical, and practical experience in areas relevant to improving understanding of long-run global change were invited to participate. The 27 participants included personnel from the Buffalo and Santa Barbara NCGIA sites, numerous representatives from the United Nations, and academics from the disciplines of Planning, Economics, and Physics. Among the academic participants were three Nobel laureates: Wassily Leontief and Lawrence Klein (Economics), and Philip Anderson (Physics).

The overall goal of the meeting was to define possibilities for collaboration and research by informing the NCGIA of current progress in global modeling, and by NCGIA's demonstrating to global modelers the state of the art and potential of GIS for modeling applications. The workshop was structured around a series of panel sessions that featured formal papers, computer demonstrations, and informal commentary. Presentations were geared to address "real world" problems and technical challenges posed by those problems. Plans are underway for the various presentations to be written up formally for publication as a book.

First Annual Mac/UB Graduate Conference in Geography (March 5-6, 1993). Along with the Graduate Students Association, The Canada-United States Trade Center, the Department of Geography at the University at Buffalo, and the Department of Geography of McMaster University, NCGIA-Buffalo helped sponsor the First Annual Mac/UB Graduate Conference in Geography, held March 5-6, 1993 in Buffalo. The purpose of the conference was to heighten the exchange of research interests and to stimulate social interaction between the Geography Departments at the two universities. The conference also provided a forum for graduate students to preview the papers they were to present in AAG '93. The conference was highly successful, with over 50 people participating in various events, and presented papers were published in monograph.

Workshop on Modeling the Impacts of Economic Integration across the Niagara Frontier (October 16, 1993). The Workshop on Modeling the Impacts of Economic Integration across the Niagara Frontier was held at the University at Buffalo on October 16, 1993. Although the conference was sponsored by the University at Buffalo's Canada-U.S. Committee, NCGIA personnel assisted with the organization and were extensively involved in the meetings. Faculty and students from McMaster University and the University at Buffalo were invited to attend this meeting which focused on the modeling of cross-boarder trade flows. Center Member Sam Cole organized and led the discussion, and other participating Center members included Mike Batty, Paul Densham, Ezra Zubrow, and PhD student Yichun Xie.

Second International Conference/Workshop on Integrating GIS and Environmental Modeling (September 26-30, 1993). The NCGIA sponsored and organized this conference in Breckenridge, CO, attended by over 600 participants. Some 80 papers were presented, including 60 selected from among the 150 abstracts submitted, and 20 invited papers. The conference included approximately 60 poster presentations, demonstrations, and tutorials. Financial support for the conference was received from: the U.S. Army Corps of Engineers; the U.S. Department of Agriculture Soil Conservation Service; the U.S. Department of Commerce, National Oceanic and Atmospheric Administration; the U.S. Department of the Interior Geological Survey, Minerals Management Service, and Fish and Wildlife Service; the U.S. Department of Energy, Oak Ridge National Laboratory; the U.S. Environmental Protection Agency; the National Aeronautics and Space Administration; Environmental Systems Research Institute; the Consortium for Earth Science Information Network (CIESIN); and Ogden Environmental and Energy Services Co.

Workshop on Exploratory Spatial Data Analysis (February 24-28). As a contribution to I14, Santa Barbara hosted a workshop to examine progress and impediments to exploratory spatial data analysis, February 24-28, 1993. The meeting was organized by Luc Anselin, Associate Director at Santa Barbara. Some 25 participants presented papers, demonstrated software, and discussed prospects for future research. Attendees came from the UK and Ireland as well as from the US. The following participants attended: Michael F. Goodchild, Waldo Tobler, Uwe Deichmann, Frank Davis, Lauretta Burke, Rusty Dodson, Joel Michaelsen, Art Getis (San Diego State University, Geography), Noel Cressie (U of Iowa,
Statistics), David Griffith (U. Toronto, Geography), Richard Becker (AT&T Bell), Paul Fatti (UC Riverside, Statistics graduate student), Stewart Fotheringham (SUNY NCGIA), John Haslett (Trinity College, Dublin, Statistics), Leigh Ihnen(SAS Institute, North Carolina), Ruben Klein (UC Riverside, Statistics graduate student), James Majure (Iowa State graduate student), M. Jammalamadaka, (UCSB Statistics), Neal Oden (Applied Biomath, New York), James Press (UC Riverside, Statistics), Lauren Scott (Cal State Fullerton, Geography), Robert Sokal (SUNY Stony Brook Ecology), Anthony Unwin (Trinity College, Dublin, Statistics), Mark Schildhauer (UCSB Social Science Computing Lab), and Allan Murray (UCSB Statistics).

GIS and Society (November 11-14, 1993). The purpose of this small workshop, held at Friday Harbor, WA, in November 1993, was to explore the broader implications of GIS and digital geographic information for society, building on a growing critique of GIS by social theorists, and interests within the GIS community regarding the technology's more profound implications. The workshop was organized by a group headed by Dr. Thomas Poiker, Simon Fraser University, and addressed such issues as empowerment, privacy, the military role of GIS, environmental equity, and the "electronic democracy". The workshop papers are available, and it is hoped that some will be published in special issues of the *International Journal of Geographical Information Systems* and *Cartography and GIS*.

3. Technical Papers published in 1993

The following titles were added to the Technical Papers series in 1993:

93-1: Three Presentations on Geographical Analysis and Modeling: Non-Isotropic Geographic Modeling; Speculations on the Geometry of Geography; and Global Spatial Analysis, by Waldo Tobler, UCSB, a collection of three short papers by NCGIA Senior Scientist Waldo Tobler.

93-2: NCGIA Secondary Education Project "GIS in the Schools" Workshop Resource Packet, by Stephen D. Palladino, UCSB, materials for GIS outreach to secondary schools, includes: prototype workshop review, GIS short course notes, resource list, and GIS glossary; also helpful to teachers wanting simple resources for GIS teaching.

93-3: Environmental Modeling with GIS: A Strategy for Dealing with Spatial Continuity, by Karen K. Kemp, UCSB, examines the incompatibility between continuous models of environmental processes and computer systems used for storing and manipulating data about environmental phenomena. Outlines an approach for addressing this problem. Includes an extensive bibliography.

93-4: Remote Sensing and GIS Integration: Towards a Prioritized Research Agenda, by John E. Estes and Jeffrey L. Star, UCSB, discusses the process used during NCGIA Initiative 12: Integration of Remote Sensing and GIS, to develop a consensus on the priorities for research, and summarizes these priorities and presents perspectives from scientists within and without the Initiative.

93-5: Teaching Introductory Geographical Data Analysis with GIS: A Laboratory Guide for an Integrated Spacestat/Idrisi Environment, edited by Rusty Dodson, Preface by Luc Anselin, UCSB,

contains student laboratory exercises for an introductory course in spatial analysis, based on an integrated computing environment using the SpaceStat and Idrisi software packages. Topics include exploratory data analysis, spatial weight matrices, spatial autocorrelation, point pattern analysis, bivariate regression, spatial ANOVA, and trend surface regression. Includes a DOS diskette with datasets and linkage software. REQUIRED SOFTWARE: SpaceStat version 1.0 or higher, and Idrisi version 4.0 or higher.

93-6: Environmental Equity in Los Angeles, by Lauretta Burke, UCSB, an MA thesis/case study of Los Angeles, investigating the relationship between the placement of environmentally hazardous industrial facilities and demographic variables.

93-7: Spatial Data Analysis and GIS: Interfacing GIS and Econometric Software, by Luc Anselin, Sheri Hudak, and Rustin Dodson, UCSB (with disk), includes software routines for extracting spatial weights matrices from common GIS packages (Arc/Info, packages GAUSS, LIMDEP, RATS, SHAZAM, and SPLUS). Contains one DOS diskette of programs and sample data.

93-8: Testing Technology Transfer Hypotheses in GIS Environments Using a Case Study Approach, edited by Harlan J. Onsrud and Jeffrey Pinto, University of Maine, and Bijan Azad, MIT, presents a scientific approach to case studies and reports two case studies that followed the outlined methodology.

93-9: GIS and the Coastal Zone: An Annotated Bibliography, compiled by Darius J. Bartlett, University College, Cork, Ireland, includes references to GIS applications for coastal zone research and management.

93-10: The NCGIA Guide to Laboratory Materials - 1993, edited by Rustin F. Dodson, UCSB, an updated version of *Technical Paper 91-20*: a compendium of information pertaining to GIS laboratory education.

93-11: African Data Viewer - compiled by Stephen D. Palladino, UCSB, designed as a resource for K-12 teachers, with data sets and a display subset of IDRISI.

Other NCGIA publications added in 1993:

Closing reports for Initiatives 3, 4, and 5

Annual GIS Bibliography for 1992, compiled by Harlan J. Onsrud and Steven Frank, U. Maine.

Annual Report Year 4 (December 1, 1991 - November 30, 1992)

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 5. The Board welcomed Susan Hanson (Clark University), Eric Sheppard (University of Minnesota), John Sprague (Washington University, St Louis), Giovanni Wiederhold (Stanford University), and Cort Willmott (University of Delaware). Meetings were held in Santa Barbara (December 1992) and Maine (June 1993) and at the end of November 1993 the members of the Board were:

Joel Morrison (US Geological Survey), Chair
Ronald Abler (Association of American Geographers)
Lawrence F. Ayers (Intergraph Corporation)
Jack Dangermond (ESRI)
John Eddy (CIESIN)
Susan Hanson (Clark University)
Roberta Lenczowski (Defense Mapping Agency)
John D. McLaughlin (University of New Brunswick)
Jeanne Savage (IBM)
Eric Sheppard (University of Minnesota)
John Sprague (Washington University)
Giovanni Wiederhold (Stanford University)
Cort Willmott (University of Delaware)

The period of service of four members - Abler, Ayers, Dangermond, and Lenczowski - was due to end after the December 1993 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. There were several changes in the membership of the Executive Committee in Year 5; on December 1, 1993 the members were Michael F. Goodchild (Director); Helen Couclelis (Associate Director, Santa Barbara); Michael Batty (Associate Director, Buffalo); Max Egenhofer (Associate Director, Maine); and Harlan Onsrud (Chair, SPC).

Scientific Policy Committee. During the year from December 1, 1992 to November 30, 1993, the Scientific Policy Committee (SPC) held formal meetings in Santa Barbara in December 1992, and in Maine in June 1993. Other informal meetings of committee members also occurred when opportunities arose. Harlan Onsrud (Maine) served as Chair of the SPC throughout the period. In addition to the Executive Committee members, the SPC included Terence Smith (Santa Barbara); Waldo Tobler (Santa Barbara; NCGIA Senior Scientist); John Estes (Santa Barbara); Barbara Buttenfield (Buffalo); Stewart Fotheringham (Buffalo); and Kate Beard (Maine). SPC meetings are also attended by selected members of the Board of Directors.

Personnel changes. Dr. Dennis Jelinski left the University at Buffalo in the spring to assume a position at the University of Nebraska. Connie Holoman, the Administrator of the Buffalo site since September 1990, left the Center to assume the position of Staff Associate to the President of the University at Buffalo in April. She was succeeded by Patricia Shyhalla, who joined the Center on July 5. Dr. Satish Mohan, Associate Professor, Civil Engineering, SUNY Buffalo, resigned his membership in the Center on June 18. Peter Rogerson resumed his position of Chair of the Department of Geography upon his return in August from a sabbatical at the Center for Advanced Study in the Behavioral Sciences, Stanford, CA. Stewart Fotheringham, who had been serving as Acting Chair, stepped down. Barbara Buttenfield began a year-long sabbatical from the University at Buffalo on Sept. 1, 1993 as a research scholar in residence at the United States Geological Survey, National Mapping Division, Reston, VA. Jim Smith, Director of Buffalo's Geographic Information

and Analysis Laboratory, resigned his position on September 7. Ms. Debbie Buffamanti, Support Specialist, was promoted to Director. Rajan Batta's appointment as Interim Chair, Department of Industrial Engineering, SUNY at Buffalo was extended for an additional year - until September 1994. Robert Reis, Professor of Law, Faculty of Law and Jurisprudence, SUNY at Buffalo accepted an invitation to become a member of the Buffalo Center in November. Rob Reis will be active in I16.

At Maine, Dr. David Tyler announced his intention to step down as Associate Director. The new AD at Maine will be Dr. Max Egenhofer effective December 1, 1993. Dr. Michael Collins was appointed Assistant Professor in the Department of Surveying Engineering and the NCGIA, effective July 1, 1993. Dr. Scott Freundschuh, while on leave from his position of Assistant Professor, Department of Geography, Memorial University of Newfoundland, Canada, has been appointed to a one-year term as a Research Associate with the NCGIA. Dr. Carl Amrhein, Associate Professor, Department of Geography, University of Toronto, was appointed to a four-month term as a Visiting Professor with the NCGIA and the Department of Surveying Engineering, from May-August 1993. He conducted research on I7, specifically on visualization of aggregation effects (the modifiable area unit problem).

At Santa Barbara, Luc Anselin was on leave during Year 5 at West Virginia University, and was replaced as Associate Director by Helen Couclelis on July 1, 1993. John Estes continued his leave at USGS in Reston, VA. Judith Parker, the Office Manager at the Santa Barbara site since March 1991, retired in October. Angela Mills joined the Center in November 1993 as a temporary assistant. The faculty of the Department of Geography was joined in late 1993 by Dar Roberts, a specialist in remote sensing from the University of Washington.

3. EXTRAMURAL SUPPORT

A. Grants and Contracts Awarded as of 11/30/93

ROCKEFELLER FOUNDATION: "Integrating GIS and Spatial Analysis Techniques for the Study of Cassava-Based Cropping Systems in Africa"; $66,000. PI: Anselin. Co-PI: Goodchild (4/1/92-3/31/94).

NATIONAL SCIENCE FOUNDATION - DISSERTATION RESEARCH GRANT: "The Archievement of Comprehensive Planning Goals: An Empirical Study of Public Service Accessibility", $10,000. PI: Couclelis. (6/1/93-9/30/94).

U.S. GEOLOGICAL SURVEY: "Topographic Framework for NSDI"; $50,000. PI: Goodchild. (1/1/94-7/31/94).

OAK RIDGE NATIONAL LABORATORY; NOAA; ARMY CORPS OF ENGINEERS; U.S. GEOLOGICAL SURVEY; NASA; CIESIN: "Second International Conference/Workshop on Integrating GIS and Environmental Modeling"; total of approx. $65,000. PI: Goodchild.

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE: Gift; $50,000. PI: Goodchild.

HITACHI AMERICA LTD (YR 2): "Cooperative Research Between Hitachi America Limited and NCGIA"; $149,811. PI: Goodchild. Co-PI's: Church and Couclelis. (4/1/93-3/31/97).

UC CAL SPACE INSTITUTE: "Exploring the Potential of Space Shuttle Photography as Metadata to Access and Manage Earth System Data"; $22,950. PI: Couclelis. (7/1/93-6/30/94).

NASA GRAD STUDENT FELLOWSHIP: "Exploring the Potential of Space Shuttle Photography as Metadata to Access and Manage Earth System Data"; $22,000. PI: Couclelis. (9/1/93-6/30/96).

DEPARTMENT OF TRANSPORTATION: "Distributed Navigable Database Design and Implementation Issues"; $135,000. PI: Goodchild. Co-PI: Church. (6/1/92-12/31/93).

US DEPARTMENT OF AGRICULTURE, FOREST SERVICE: "Spatial Decision Support Systems for Forest Planning: The Development of FEMdss"; $67,498. PI: Church. (10/1/93-7/30/94).

USDA PSW-91-0030CA: "Spatial Decision Support Systems for Forest Plan Implementation: an Update"; $27,000. PI: Church. (9/15/92-5/31/94).

USDA FS PSW-92-0039CA: "Spatial Decision Support Systems for Forest Plan Implementation: an Update"; $26,959. PI: Church. (9/15/92-4/30/94).

CA DEPARTMENT OF FORESTRY/FIRE PROTECTION: "Vegetation Change in Blue Oak and Blue Oak/Foothill Pine Woodland"; $64,420. PI: Davis. (6/15/91-3/31/94).

NASA (DEPT SE): "Using Remote Sensing to Evaluate a Socio-Economic and Ecological Model of Land Use Change"; $159,711. PI: Davis. (10/1/91-9/30/94).

JET PROPULSION LAB (NASA flow-through), "Microwave Modeling for ERS-1 (A supplement to GIS Fusion and Analysis of High-Resolution Remote Sensing and Ground Truth Data)", $15,000. PI: Davis. (9/1/92-3/31/94).

ENVIRONMENTAL PROTECTION AGENCY: "Advanced Remote Sensing and Geographic Information System Integration Demonstration and Basic Research Cooperative Agreement"; $49,967. PI: Estes. Co-PI: Davis. (10/1/92-12/31/93).

YOSEMITE ASSOCIATION: "Vegetation Mapping of Yosemite National Park Using Digital Remotely Sensed Data and GIS Environmental Coverages for Inventory and Analysis (CRSEO)"; $83,054. PI: Davis. (7/1/93-6/30/95).

NASA: "Application of Remotely Sensed Data to Actual Evaporation Modeling Using A Supply-Demand Approach and Landscape Stratification (CRSEO)"; $193,012. PI: Davis. (1/1/93-12/31/96).

IBM: "A Spatial Analysis and Decision Support for Conservation of Biological Diversity"; $301,221. PI: Davis; Co-PI: Goodchild. (1/1/93-1/31/96).

JET PROPULSION LAB: "Biomass Modeling of the Ponderosa Pine Forests of Western North America with SIR-C-SAR for Input to Ecosystem Models (CRSEO)"; $119,500. PI: Davis. (10/1/92-3/31/94).

NASA: "Scale Dependence of Area Integrated Flux over the FIFE Site (CRSEO)"; $85,000. PI: Davis. (7/1/93-6/30/94).

CA DEPT OF FORESTRY: "Compiling a Digital Map of Biodiversity Management Status for California (CRSEO); $10,943. PI: Davis. (4/1/93-3/31/94).

CA DEPT OF FISH AND GAME: "An Integrated Geographic Information System for Modeling Wildlife Species Distributions (CRSEO)"; $50,000. PI: Davis. ((4/1/93-6/30/95).

NATIONAL FISH AND WILDLIFE FOUNDATION: "Compiling a Digital Map of Biodiversity Management Status for California (CRSEO)"; $12,000. PI: Davis. (4/1/93-3/31/94).

NASA NAGW8-929: "Support of the WETNET Program"; $74,996. PI: Estes. (7/20/92-12/31/93).

EG&G ENERGY MEASUREMENT: "Improved Integration of Remote Sensing Imagery with Geographic Information Systems: Multi-Image Registration Algorithm Comparison"; $49,029. PI: Estes. (3/8/93-9/30/93).

EG&G ENERGY MEASUREMENT (Increment #1): "Improved Integration of Remote Sensing Imagery with Geographic Information Systems: Multi-Image Registration Algorithm Comparison"; $11,104. PI: Estes. (3/15/93-3/31/94).

HEWLETT PACKARD COMPANY: "Distributed Data and Processing Prototype"; $7,661. PI: Estes. 7/1/93-10/15/93.

CIESIN (Year 2): "Migration of Scientific Information into the Decision-making Arena"; $159,543. PI: Estes. (6/1/93-5/31/94).

NASA NAGW-1743: "Remote Sensing Information Science Research Support and Coordination for Global Science in the EOS Era"; $904,932. PI: Estes. (5/1/93-4/30/94).

CALIFORNIA SPACE INSTITUTE: "Integrating Fractal Analysis and Logistic Regression Models to Predict Human Landscape Disturbance"; $24,977. PI: Estes. (7/1/93-6/30/94).

NASA GRADUATE STUDENT FELLOWSHIPS: "Using Fractal Analysis and Image Based Logistic Regression Models to Predict Anthropogenic Landscape Disturbance"; $21,000. PI: Estes. (9/1/93-5/31/95).

NSF SES-9207836: "Reasoning and Inference in Spatial Knowledge Acquisition: The Cognitive Map as an Internalized GIS"; $115,525. PI: Golledge. (8/1/92-7/31/94).

NATIONAL EYE INSTITUTE: "Navigation Aid for the Visually Impaired"; $437,096. Co-PI: Golledge. (8/1/92-6/30/96).

UC BERKELEY: "A GIS Data Model for Transportation Modeling and Planning (Dissertation grant for Mei-po Kwan)"; $20,272. Co-PI: Golledge. (8/1/93-7/31/94).

NSF SES-9207836: "Reasoning and Inference in Spatial Knowledge Acquisition: The Cognitive Map as an Internalized GIS"; $15,000. PI: Golden. (5/1/92-7/31/94).

UC BERKELEY: "A GIS Based Computational Process Model of Travel Destinations in Activity Scheduling (includes Mei-po Kwan Fellowship $6,809)"; $51,865. PI: Golledge. (8/1/92-3/31/94).

NSF IRI-9117094: "Toward a System that Supports Conceptual Modeling in Data Intensive Scientific Investigation"; $610,808. PI: Smith. (9/15/91-8/31/94).

NASA AND NSERC (revised form of previously announced grant): "Surface Energy and Water Balances of Forest and Wetland Subsystems in the Boreal Forest: Surface-Atmosphere Links and Ecological Controls"; $200,000 from NASA to Jelinski, $300,000 from NSERC to MacCaughey and Lafleur. PI: Jelinski, McCaughey, Lafleur. (1/1/93-12/31/96).

EMPIRE EXPLORATION: "Digital Base Map Registration"; $22,723. PI: Buttenfield. (8/1/93-7/31/94).

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE: "Representation of Wildfires in Geographical Information Systems"; $3,950. PI: Mark (for PhD student M. Yuan) (7/1/93-6/30/94).

UNIVERSITY OF MIAMI: "Ecological Sustainability and Human Institutions: Phase II"; $25,000. PI: Zubrow. (10/1/93-9/30/96).

INTERGRAPH CORPORATION: "Spatial Relations." $157,625. co-PI: Egenhofer and Frank. (7/1/92-6/30/95).

NATIONAL SCIENCE FOUNDATION (USGS flow through): "Topographic Framework for National Spatial Data Infrastructure." $34,154. co-PI: Onsrud.

NATIONAL SCIENCE FOUNDATION: "Formalization, Inference, and Query Processing of Spatial Relations in Geographic Space"; $97,325. PI: Egenhofer.

UNIVERSITY OF MAINE OFFICE OF RESEARCH AND PUBLIC SERVICE: "Database Requirements for Vehicle Navigation Systems"; $5,000. PI: Egenhofer. Summer 1993.

B. Equipment and Software Acquisitions

Maine

Macintosh LC III 8/160 with color monitor
ARC/INFO for Alpha 3000/300 OSF/1 platform
Quintus MacProlog 4.0 software licenses (10)

Buffalo

An IBM Model 700 Portable Computer, Cornerstone 120 Grey Scale Monitor, and Envisions 6000 Color Flatbed Scanner were purchased under the World University Games (WUGS) Grant for the WUGS Digital Representation Project.

Three Dell 486 Computers were acquired for the Geographic Information and Analysis Laboratory, as was an Apple ColorOne flatbed scanner. Additional equipment was purchased to furnish a "Visitor and Demonstration" room in the Geographic Information and Analysis Laboratory (GIAL). Included were a Macintosh Quadra 800, a Macintosh Centris 650, and a Rasterops 24 STV Video Board.

NCGIA-Buffalo's office equipment was upgraded with the purchase of Macintosh Quadra 800 with Powerbook, two Macintosh Centris 650s and a LaserWriter Pro 630 laser printer .

Santa Barbara

In November, 1993, NCGIA experienced a burglary that disrupted operations helpless for months. Below is a list of the new equipment that was ordered to replace items stolen.

IBM RS/6000 Model 370
(2) IBM RS/6000 32MB memory boards and SIMMS
(2) IBM RS/6000 Model 370's
(1) CD-ROM Model 5
(6) IBM RS/6000 Model 250'S
(1) IBM RS/6000 Model 250 + diags
(3) Gender changers
(2) Serial Cables
RS 232 Breakout box
10 BaseT Solid Conductor Wire
UTP Termination test kit
RJ-45 Connectors, Solid Core
Punch down tool
(11) TP Transceiver
TP Breakout Box & Bounceback
Ethernet Workgroup Hub
Line Aid & Tone Tracer
UB Buffered Repeater
(28) 8MB PS/2 SIMMS

Other items acquired by the Santa Barbara site in Year 5:

Transceiver and Asante adapter for portable PC

Zenith portable PC
1 Asante Friendly-net Thick adapter
1 TCL Thick ethernet adapter
1 Adobe Postscript cartridge for HP LaserJet II
1 120 Mb ESDI disk drive for PS/2
2 ARC/View Manual for Unix
1 Quantum 85 Mb internal disk drive for Mac Se
1 HP Laserjet IV-M
1 Apple Mac llsi, 3MB RAM, 40 Mb HD
1 14" color display
1 Apple keyboard II
1 Word and Excel software
1 Adobe Postscript cartridge for HP LaserJet II
1 AHA 1640 kit Adaptec SCSI adapter for IBM PS 2 model 80 (kit)
1 PP-02MF-A Adapter for 3l5 to 5.25" form factor disk
1 Mac Powerbook 165C w/120 Mb disk, 4 Mb memory for Hitachi
1 upgrade from 4Mb to 10Mb memory, for Hitachi
1 LC-II memory update from 4Mb to 10Mb
1 Microsoft Word for Windows
1 Wordperfect 5.1 upgrade media and doc. kit for IBM RS/6000
1 Wordperfect 5.1 single user license upgrade
2 Micro Thin net transceiver w/pigtail
1 Maxtor 213Mb SCSI disk drive
1 SAM Anti-virus software for Mac
2 Excel 4.0 for Mac
1 Conner 85Mb external disk drive for Mac IIx
1 90’ Plenum Thin Ethernet cable w/ends, for Caltrans
1 1.05Gb Seagate fast SCSI-2disk drive
1 Mounting kit for Sparc-10 internal drive

APPENDIX 1 - PUBLICATIONS

A. Articles published or formally accepted in refereed journals

Anselin, L., R.F. Dodson, and S. Hudak (1993) Linking GIS and spatial data analysis in practice. *Geographical Systems* 1(1): 3-23.

Armstrong, M.P. (1993) On automated geography. *Professional Geographer* 45: 440-442.

Armstrong, M.P., and P. Lolonis (1993) Location-allocation models as decision aids in deliniating administrative regions. *Computers, Environment and Urban Systems* 17(2): 153-174.

Batty, M. (1992) Urban modeling in computer-graphic and geographic information system environments. *Environment and Planning B* 19: 663-685.

Batty, M**.** (1993) On the electronic frontier: building the information highway. *Environment and Planning B* 20: 121-122.

Batty, M (1993) The geography of cyberspace. *Environment and Planning B* 20: 615-616.

Batty, M., and B. Harris (1993) Locational models, geographic information and planning support systems. J*ournal of Planning Research and Education* 12: 102-115.

Baveja, A., R. Batta, J.P. Caulkins, and M.H. Karwan (1993) Modeling the response of illicit drug markets to local enforcement. *Socio-Economic Planning Sciences* 27(2): 73-79.

Beard, M.K. and W.A. Mackaness (in press) Visual access to data quality in geographic information systems. *Cartographica*.

Buttenfield, B.P. (in press) Representing spatial data quality. *Cartographica*.

Buttenfield, B.P. (in press) Mapping data quality. Preface to Special Issue on Mapping Data Quality (B.P. Buttenfield, Guest Editor). *Cartographica*.

Chithambaram, R., K. Beard, and R. Barrera (in press) Reversible polygon skeletonization for map generalization using an object-oriented approach. *International Journal of Geographical Information Systems*.

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

Church, R.L., and O.B. Schoepfle (1993) The choice alternative to school assignment. *Environment and Planning B* 21(1): 79-99.

Church, R.L., and A.T. Murray (1993) Modeling school utilization and consolidation. *Journal of Urban Planning and Development-ASCE* 119(1): 23-38.

Church, R.L., and J. Current (1993) Maximal covering tree problems. *Naval Research Logistics Quarterly* 40(1): 129-142.

Couclelis, H. (1993) The last frontier. *Environment and Planning B* 20(1): 1-4.

Davis, F.W., Y. Wang, and J.M. Melack (1993) Simulated and observed backscatter at P-, L-, and C-bands from ponderosa pine stands. *IEEE Transactions on Geoscience and Remote Sensing* 31(4): 871-879.

Davis, F.W., and R.M. Callaway (1993) Vegetation dynamics, fire, and the physical environment in coastal central California. *Ecology* 74(5): 1567-1578.

Davis, F.W., D.M. Stoms, C.B. Cogan, M.O. Painho, *et al*. (1993) Geographic analysis of California Condor sighting data. *Conservation Biology* 7(1):148-159.

Ding, Y., A. Baveja, A., and R. Batta, (in press) Implementing Larson and Sadiq's location model using a geographic information system. *Computers and Operations Research* 21(4): 447-454.

Egenhofer, M. (in press) Pre-processing queries with spatial constraints. *Photogrammetric Engineering and Remote Sensing*.

Egenhofer, M. (in press) Deriving the composition of binary topological relations. *Journal of Visual Languages and Computing*.

Egenhofer, M. (in press) Definitions of line-line relations for geographic databases. *IEEE Database Engineering*.

Egenhofer, M. (in press) A model for detailed binary topological relationships. *Geomatica*.

Egenhofer, M.J. and J.R. Richards (1993) Exploratory access to geographic data based on the map-overlay metaphor. *Journal of Visual Languages and Computing* 4(2): 105-125.

Egenhofer, M., and J. Sharma (1993) Assessing the consistency of complete and incomplete topological information. *Geographical Systems* 1(1): 47-68.

Egenhofer, M., E. Clementini, and P. di Felice (in press) Topological relations between regions with holes. *International Journal of Geographical Information Systems*.

Ehrlich, E., J.E. Estes, and A. Singh (1993) Applications of NOAA-AVHRR 1 km data for environmental monitoring. *International Journal of Remote Sensing* 15(1): 145-161.

Estes, J.E., J.L. Star, M.F. Goodchild, T. Cary, *et al*. (1993) The NCGIA core curriculum in remote sensing. *Photogrammetric Engineering and Remote Sensing* 59(6): 945-948.

Fotheringham, A.S. (1993) On the future of spatial analysis - the role of GIS. *Environment and Planning A* NSI: 30-34.

Fotheringham, A.S. (1993) The retail environment - review of K. Jones and J. Simmons. *Annals of Regional Science* 27(2): 184-185.

Fotheringham, A.S., and P.A. Rogerson (1993) GIS and spatial analytical problems. *International Journal of Geographical Information Systems* 7(1): 3-19.

Fotheringham, A.S. (1993) Spatial musings. *Environment and Planning A* 25(2): 156-158.

Fotheringham, A.S. (1993) Chain image and sotre-choice modeling - the effects of income and race. *Environment and Planning A* 25(2): 179-196.

Frank, A.U. (1992) Qualitative spatial reasoning about distances and directions in geographic space. *Journal of Visual Languages and Computing* 3(4): 343-371.

Frank, S. (in press) The national spatial data infrastructure: designing navigational strategies. *Journal of the Urban and Regional Information Systems Association*.

Frank, S. (in press) Cataloging digital geographic data in the information infrastructure. *Information Processing and Management.*

Golledge, R.G. (in press) Computational-process modeling of household travel decisions using a geographical information system. *Papers in Regional Science*.

Goodchild, M.F. (1993) 10 years ahead - Dobson's automated geography in 1993. *Professional Geographer* 45(4): 444-446.

Goodchild, M.F., L. Anselin, and U. Deichmann (1993) A framework for the areal interploation of socioeconomic data. *Environment and Planning A* 25(3): 383-397.

Goodchild, M.F., B. Klinkenberg, and D.G. Janelle (1993) A factorial model of aggregate spatio-temporal behavior - application to the diurnal cycle. *Geographic Analysis* 25(4): 781-786.

Goodchild, M.F., and D.M. Mark (1993) GIS, Geography, and NCGIA - response. *Professional Geographer* 45(2): 216-220.

Hudak, P.F. (1993) Optimizing environmental monitoring networks with direction-dependent distance thresholds. *Environmental Monitoring and Assessment* 28(1): 53-60.

Hudak, P.F., H.A. Loaiciga, and F.A. Schoolmaster (1993) Application of GIS to groundwater monitoring network design. *Water Resources Bulletin* 29(3): 383-390.

Hudak, P.F., and H.A. Loaiciga (1993) An optimization method for monitoring network design in multilayered groundwater flow systems. *Water Resources Research* 29(8): 2835-2845.

Hudak, P.F., H.A. Loaiciga, and M.A. Marino (in press) Regional scale groundwater monitoring via integer programming. *Journal of Hydrology*.

Hudak, P.F., K.M. Clements, and H.A. Loaiciga (1993) Water-table correction factors applied to gasoline contamination. *Journal of Environmental Engineering-ASCE* 119(3): 578-584.

Hunter, G.J., and M.F. Goodchild (in press) Dealing with uncertainty in spatial databases: a simple case study. *Photogrammetric Engineering and Remote Sensing*.

Jeffress, G.A., and L.C. Holstein (1993) An international survey of real property transaction recording costs and some characteristics: A preliminary evaluation. *Journal of the Urban and Regional Information Systems Association* 5(1): 53-66.

Jelinski, D.E. (1993) Associations between environmental heterogeneity, heterozygosity, and growth rates of Populus tremuloides in a cordilleran landscape. *Artic and Alpine Research* 25(3): 183-188.

Jemaa, B.F., M.Marino, and H.A. Loaiciga (in press) Multivariate geostatistical design of groundwater monitoring networks. *Journal of Water Resources Planning and Management.*

Kainz, W., M.J. Egenhofer, and I. Greasley (1993) Modelling spatial relations and operations with partially ordered sets. *International Journal of Geographical Information Systems* 7(3): 215-229.

Keller, E.A, and H.A. Loaiciga (in press) Earthquakes, fluid pressure, and mountain building. *Geophysical Research Letters*.

Krishnamurthy, N.N., R. Batta, and M.H. Karwan (1993) Developing conflict-free routes for automated guided vehicles. *Operations Research* 41(6): 1077-1090.

Leipnik, M.R., K.K. Kemp, and H.A. Loaiciga (1993) Implementation of GIS for water resources planning and management. *Journal of Water Resources Planning and Management-ASCE* 119(2): 184-205.

Loaiciga, H.A., and L.G. Everett (in press) Review of groundwater quality monitoring network closure. *Journal of Hydraulic Engineering*.

Loaiciga, H.A., M.R. Leipnik, P.F. Hudak, and M.A. Marino (in press) Effective conductivity of nonstationary aquifers. *Stochastic Hydrology and Hydraulics.*

Loaiciga, H.A., J. Michaelsen, S. Garver, L. Haston, *et al.* (1993) Droughts in river basins of the western United States. *Geophysical Research Letters* 20(21): 2411-2411.

Loaiciga, H.A., L. Haston, and J. Michaelsen (1993) Dendrohydrology and long-term hydrologic phenomena. *Reviews of Geophysics* 31(2): 151-171.

Loaiciga, H.A., R.B. Leipnik, M.A. Marino, and P.F. Hudak (1993) Stochastic groundwater flow analysis in the presence of trends in heterogeneous hydraulic conductivity fields. *Mathematical Geology* 25(2): 161-176.

Mackaness, W.A., and M.K. Beard (1993) Use of graph theory to support map generalization. *Cartography and Geographic Information Systems* 20(4): 210-221.

McGwire, K., M. Friedl, and J.E. Estes (1993) Spatial structure, sampling design and scale in remotely-sensed imagery of a California savanna woodland. *International Journal of Remote Sensing* 14(11): 2137-2164.

Niemeier D.A., and M.K. Beard (1993) GIS and transportation planning - a case study. *Computers, Environment and Urban Systems* 17(1): 31-43.

Onsrud, H.J., and J.K. Pinto (1993) Evaluating correlates of GIS adoption success and the decision process of GIS acquisition. *Journal of the Urban and Regional Information Systems Association* 5(1): 18-39.

Onsrud, H.J., and J.K. Pinto (1993) Survey and comparative analysis of alternative names for an academic discipline, *Surveying and Land Information Systems*, 53(3): 164-178.

Prasad, S.Y., and R. Batta (1993) Determining efficient facility locations on a tree network operating as a FIFO M/G/1 queue. *Networks* 23(7): 597-603.

Sivakumar, R.A., R. Batta, K. Tehrani, and P. McCutcheon (1993) Scheduling repairs at Texas Instruments. *Interfaces* 23(4): 68-74.

Sivakumar, R.A., R. Batta, and M.H. Karwan (1993) A network-based model for transporting extremely hazardous materials. *Operations Research Letters* 13(2): 85-93.

Sorenson, P.A., and D.P. Lanter (1993) Two algorithms for determining partial visibility and reducing data structure induced error in viewshed analysis. *Photogrammetric Engineering and Remote Sensing* 59(7): 1149-1160.

Star, J.L., J.E. Estes, and F. Davis (1993) Improved integration of remote sensing and GIS - A background to NCGIA Initiative 12. *Photogrammetric Engineering and Remote Sensing* 59(6): 945-948.

Stoms, D.M., and K. Beardsley (1993) Compiling a digital map of areas managed for biodiversity in California. *Natural Areas Journal* 13(3): 177-190.

Stoms, D.M., F.W. Davis, C.B. Cogan, M.O. Painho, B.W. Duncan, J. Scepan, and J.M. Scott (1993) Geographic analysis of California condor sighting data. *Conservation Biology* 7: 148-159.

Stoms, D.M., and J.E. Estes (1993) A remote sensing research agenda for mapping and monitoring biodiversity. *International Journal of Remote Sensing* 14(8): 3505.

Zektser, I.S., and H.A. Loaiciga (1993) Groundwater fluxes in the global hydrologic cycle - past, present and future. *Journal of Hydrology* 144(1-4): 405-427.

B. Books

Eagles, D. Munroe, editor (in press) *Spatial and Contextual Models in Political Research.* London: Taylor and Francis.

Fotheringham, A.S., and P. Rogerson, editors (in press) *GIS and Spatial Analysis.* London: Taylor and Francis.

Goodchild, M.F., B.O. Parks, and L.T. Steyaert, editors (1993) *Environmental Modeling with GIS*. New York: Oxford University Press.

Masser, I. and H.J. Onsrud, editors (1993) *Diffusion and Use of Geographic Information Technologies*. Dordrecht: Kluwer Academic Publishers.

Onsrud, H.J., and G. Rushton, editors (in press) *Sharing Geographic Information*. Piscataway: CUPR-Rutgers.

Plane, D., and P.A. Rogerson (in press) *The Geographical Analysis of Population: with Applications to Planning and Business*. New York: Wiley.

C. Articles in Refereed Conference Proceedings

Egenhofer, M.J. (1993) What's special about spatial? Database requirements for vehicle navigation in geographic space. In P. Buneman and S. Jajodia, editors, *Proceedings, SIGMOD '93*, Washington, DC, May 26-28, 1993, *SIGMOD Record* 22(2): 398-402.

Egenhofer, M.J., and J. Sharma (1993) Topological relations between regions in R^2 and Z^2 . In D. Abel and B.C. Ooi, editors, *Advances in Spatial Databases, Proceedings of the Third International Symposium on Large Spatial Databases,* Singapore, June 23-25, 1993 (Lecture Notes in Computer Science, Vol. 692). Berlin: Springer-Verlag, 316-336.

Volta, G.S., and M.J. Egenhofer (1993) Interaction with GIS attribute data based on categorical coverages. In A.U. Frank and I. Campari, editors, *Spatial Information Theory, A Theoretical Basis for GIS, Proceedings, COSIT '93*, Elba Island, Italy, September 1993 (Lecture Notes in Computer Science, Vol. 716). Berlin: Springer-Verlag, 215-233.

D. Articles in other outlets

Al-Taha, K., and A. Frank (1993) What a temporal GIS can do for cadastral systems. *Proceedings, First Conference on GIS and Applications, Sharjah, United Arab Emirates, February 8-10, 1993* 13: 1-16.

Al-Taha, K.K., R.T. Snodgrass, and M.D. Soo (1993) Bibliography on spatiotemporal databases. *SIGMOD Record* 22(1): 59-67.

Anselin, L. (1993) Discrete space autoregressive models. In M.F. Goodchild, B. Parks and L.T. Steyaert, editors, *GIS and Environmental Modeling*. New York: Oxford University Press, pp. 454-69.

Anselin, L., S. Hudak, and R. Dodson (1993) Spatial data analysis and GIS: interfacing GIS and econometric software. *NCGIA Technical Report 93-7*. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Anselin, L., and A. Getis (1993) Spatial statistical analysis and geographic information systems. In Manfred M. Fischer and Peter Nijkamp, editors, *Geographic Information Systems, Spatial Modelling and Policy Evaluation*. Berlin: Springer Verlag, pp. 35-49 (reprint of article in *Annals of Regional Science*).

Azad, Bijan, and L. Wiggins (1993) Institutional issues in the transfer of GIS technology to organization. *Proceedings, First Conference on GIS and Applications, Sharjah, United Arab Emirates, February 8-10, 1993.*

Batty, M., and P. Longley (1993) Speculations on fractal geometry in spatial dynamics. In P. Nijkamp and A. Reggiani, editors, *Nonlinear Evolution of Spatial Economic Systems.* Berlin: Springer-Verlag, pp. 203-222.

Batty, M., with A.S. Fotheringham, and P. Longley (1993) Fractal geometry and urban morphology. In N. Lam and L. De Cola, editors, *Fractals in Geography*. Englewood Cliffs, NJ: Prentice-Hall, pp. 243-261.

Buttenfield, B.P. (1993) Formalizing rules for gray tone selection in contour mapping. *Proceedings ACSM/ASPRS, New Orleans, LA* 1: 52-61.

Buttenfield, B.P. (1993) Proactive graphics for GIS: prototype tools for query, modeling and display. *Proceedings, Auto-Carto 11, Minneapolis, MN, October 1993*, pp. 377-385.

Buttenfield, B.P., and M.K. Beard (in press) Graphical and geographical components of data quality. In *Visualization in Geographic Information Systems.* London: Belhaven Press.

Buttenfield, B.P. (in press) Scientific visualization for environmental modeling: interactive and proactive graphics. *Proceedings, 2nd International Conference on Integrating GIS and Environmental Modeling, Breckenridge, CO, September 1993.*

Buttenfield, B.P., and C.R. Weber (1993) Visualization and hypermedia in GIS. In D. Medyckyj-Scott, and H. Hearnshaw, editors, *Human Factors in Geographic Information Systems*. London: Belhaven Press, pp. 136-147.

Calkins, H.W., and R. Weatherbe (in press). Taxonomy of spatial data sharing. In I. Masser and H. Onsrud, editors, *Diffusion and Use of Geographic Information Technologies*. Dordrecht: Kluwer Academic Publishers.

Church, R.L., and K. Barber (in press) Disaggregrating forest management plans to treatment areas. *Proceedings of the Stand Inventory Technology Conference of 1992.*

Church, R.L., and A.T. Murray (in press) Adjacency constraint aggregration. *Proceedings of the International Symposium on Analysis and Management Decisions in Forestry, Valdivia, Chile, 1993*.

Cole, H. Sam (1992) Accounting for multi-cultural futures. *Proceedings of the Eleventh World Futures Studies Federation, Budapest, Hungary*, pp. 13-21.

Cole, H. Sam (1993). *The Outlook for Western New York*. Rockefeller Institute. Albany: SUNY Press, pp. 43-80.

Davis, F.W. (1993) Behavior and environment: psychological and geographical approaches. In R.I. Miller, editor, *Mapping the Diversity of Nature*. Amsterdam: Elsevier Science Publishers.

Davis, F.W., and D.M. Stoms (1992) Gap analysis of biodiversity in California. In H.M. Kerner, editor, *Symposium on Biodiversity of Northern California*. Wildland Resources Center Report 29, University of California, Berkeley, pp 23-29.

Densham, P.J., and M.P. Armstrong (1993) Supporting visual interactive locational analysis using multiple abstracted topological structures. *Proceedings, Auto Carto 11, Minneapolis, MN, November, 1993*, pp. 12-22.

Densham, P.J. (1993) Integrating GIS and parallel processing to provide decision support for hierarchical location selection problems. *Proceedings, GIS/LIS '93, Minneapolis, MN, November, 1993*, pp. 170-179.

Dibble, C., and P.J. Densham (1993) Generating interesting alternatives in GIS and SDSS using genetic algorithms. *Proceedings, GIS/LIS '93, Minneapolis, MN, November, 1993*, pp. 180-189.

DePinto, J.V., J.F. Atkinson, H.W. Calkins, P.J. Densham, W. Guan, H. Lin, F. Xia, P.W. Rogers, T. Slawecki and W.L. Richardson (in press) Development of GEO-WAMS: a modeling support system for integrating GIS with watershed analysis models. *Proceedings, Second International Conference/Workshop on Integrating GIS and Environmental Modeling, Breckenridge, CO, September, 1993.*

Dodson, R. (1993) Teaching introductory geographical data analysis with GIS: a laboratory guide for an integrated Spacestat/IDRISI environment. *NCGIA Technical Report 93-5*. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Eagles, M. (in press) Elections. In James P. Bickerton and Alain-G. Gagnon, editors, *Canadian Politics: an Introduction to the Discipline, 2nd edition.* Peterborough: Broadview Press.

Eagles, M. (in press) The study of Canadian electoral behaviour: a comment on approaches and methods. *Proceedings of the Atlantic Provinces Political Studies Association Annual Conference, St. Francis Xavier University, Antigonish, Nova Scotia, 1993.*

Egenhofer, M.J., and J. R. Herring (1993) Querying a geographical information system. In D. Medyckyj-Scott and H.M. Hearnshaw, editors, *Human Factors in Geographical Information Systems*. London: Belhaven Press, 124-135.

Egenhofer, M.J., and J.R. Richards (1993) The geographer's desktop: a direct-manipulation user interface for map overlay. *Proceedings, Auto-Carto 11, Minneapolis, MN, October 30-November 1, 1993,* pp. 63-71.

Egenhofer, M.J., J. Sharma, and D.M. Mark (1993) A critical comparison of the 4-intersection and 9-intersection models for spatial relations: formal analysis. *Proceedings, Auto-Carto 11, Minneapolis, MN, October 30-November 1, 1993,* pp. 1-11.

Ehlers, M. (1992) Remote sensing and geographic information systems: image-integrated geographic information systems. In A.I. Johnson, C.B. Pettersson, and J.L. Fulton, editors, *Geographic Information Systems and Mapping - Practices and Standards*. Philadelphia, PA: American Society for Testing and Materials.

Flewelling, D.M., and M.J. Egenhofer (1993) Formalizing importance: parameters for settlement selection from a geographic database. *Proceedings, Auto-Carto 11, Minneapolis, MN, October 30-November 1, 1993*, 167-175.

Frank, A.U. (1992) Spatial reasoning: theoretical considerations and practical applications. *Proceedings, EGIS '92, Munich, Germany, March 23-26, 1992*, 1: 310-319.

Frank, S. (1993) Using visualization techniques to examine the effects of random control points on grid interpolation. *Proceedings, GIS/LIS '93, Minneapolis, MN, November 2-4, 1993*, 1: 226-232.

Franzosa, R.D. and M.J. Egenhofer (1992) Topological spatial relations based on components and dimensions of set intersections. In R. Melter and A. Wu, editors, *Proceedings, Vision Geometry, International Society for Optical Engineering (SPIE)*, 1832: 236-246.

Goodchild, M.F. (1993) Integrating the spatial data technologies. *Proceedings, On Common Ground Conference '93*, pp. 33-39.

Goodchild, M.F., and K.K. Kemp (1992) GIS research and education in the USA (in Russian). *Vestnik Moskovskogo Universiteta*, Geography Series 4: 68-72.

Haller, J..R., W.R. Ferren, R.M. Callaway, D.C. Odion, and F.W. Davis (1992) A phytogeographic comparison of the vascular flora of the wetlands of fish slough with the floras of neighboring desert basins. In C.A.

Hall *et al.*, editors, *The History of Water: Eastern Sierra Nevada, Owens Valley, White-Inyo Mountains*. White Mountain Research Station Volume 4, University of California, Los Angeles, pp. 211-222.

Hollander, A.D., F.W. Davis, and D.M. Stoms (1993) Hierarchical representation of species distributions using maps, images and sighting data. In R.I. Miller, editor, *Mapping the Diversity of Nature*. Chapman & Hall.

Hudak, P.F., H.A. Loaiciga, and M.A. Marino (in press) Regional scale ground water monitoring, methods and case studies. Contribution W-761, California Water Resources Center, Riverside CA.

Klosterman R., and Xie, Y. (1993) ECONBASE: economic base analysis. In R. Klosterman, R. Brail, and E. Bossard, editors, *Spreadsheet Models for Urban and Regional Analysis*. Center for Urban Policy Research. Piscataway, NJ: Rutgers University Press, pp. 161-182.

Klosterman R., and Xie, Y. (1993) SHFT-SHR: local employment projection. In R. Klosterman, R. Brail, and E. Bossard, editors, *Spreadsheet Models for Urban and Regional Planning Analysis*. Center for Urban Policy Research. Piscataway, NJ: Rutgers University Press, pp. 183-204.

Leitner, M., and B.P. Buttenfield (1993) Dasymetric mapping: a cartographic approach to map overlay. *Proceedings, International Conference on GIS, Salzburg, Austria, July 1993*, pp. 41-50.

Leung, L., M.F. Goodchild, and C.C. Lin (1993) Visualization of fuzzy scenes and probability fields. In H.J. Newton, editor, *Computing Science and Statistics, Volume 24: Graphics and Visualization (Proceedings of the 24th Symposium on the Interface)*. Fairfax Station, VA: Interface Foundation of North America, pp. 416-422.

Mackaness, W.A. (in press) Knowledge of the synergy of generalization operators in automated map design. *Combined Symposium of ISPRS Commission II and the Sixth Canadian Conference on Geographic Information Systems, June 6-10, 1994.*

Mackaness, W.A.(in press) Automated cartography and the human paradigm. Abstract submitted for presentation at the *Symposium on Cartographic Design and Research, Ottawa, Canada, August 7-8, 1994.*

Mackaness, W., and K. Beard (1993) Visualization of interpolation accuracy. *Proceedings, Auto-Carto 11, Minneapolis, MN, October 30-November 1, 1993*, pp. 228-237.

Mark, D.M. (1993) Human spatial cognition. In D. Medyckj Scott and H.M. Hearnshaw, editors, *Human Factors in Geographical Information Systems.* London: Belhaven Press, pp. 51-60.

Mark, D.M. (1993) Toward a theoretical framework for geographic entity types. In A.U. Frank and I. Campari, editors, *Spatial Information Theory: A Theoretical Basis for GIS.* Berlin: Springer-Verlag, Lecture Notes in Computer Sciences No. 716, 1993, pp. 270-286.

Mark, D.M. (1993) A theoretical framework for extending the set of geographic entity types in the U.S. Spatial Data Transfer Standard (SDTS). *Proceedings, GIS/LIS '93, Minneapolis, MN, November 1993*, 2: 475-483.

McGranaghan, M. (1993) Applications of artificial intelligence to extracting and refining locality information. In R. Fortuner, editor, *Advances in Computer Methods for Systematic Biology*. Baltimore: The Johns Hopkins University Press.

McGwire, K., and M.F. Goodchild (in press) Data quality. In J.L. Star and J.E. Estes, editors, *Integration of GIS and Remote Sensing.* Cambridge University Press.

Odion, D.C., R.M. Callaway, W.R. Ferren and F.W. Davis (1992) Vegetation of Fish Slough, an Owens Valley wetland ecosystem. In C.A. Hall *et al.*, editors, *The History of Water: Eastern Sierra Nevada, Owens Valley, White-Inyo mountains.* White Mountain Research Station Volume 4, University of California, Los Angeles, pp. 171-197.

Onsrud, H.J. (1993) Evidence generated from GIS. *GIS Law* 1(3): 1-9.

Onsrud, H.J. and S. Frank (1993) Annual GIS Bibliography for 1992. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Onsrud, H.J., J.K. Pinto, and B. Azad, editors (1993) Testing technology transfer hypotheses in GIS environments using a case study approach. *Technical Report 93-8*. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Paiva, J., M.J. Egenhofer, and A.U. Frank (1992) Spatial reasoning about flow directions: towards an ontology for river networks. *Proceedings, ISPRS XVII Congress, Washington, DC, 1992*, 29: 318-324.

Palladino, S.D. (1993) GIS in the Schools Workshop Resource Packet. *NCGIA Technical Report 93-2*. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Palladino, S.D., and M.F. Goodchild (1993) A place for GIS in the secondary schools: lessons from the NCGIA Secondary Education Project. *Geo Info Systems* 3(4): 45-49.

Pinto, J.K. and H.J. Onsrud (1993) Correlating adoption factors and adopter characteristics with successful use of geographic information systems. In I.Masser and H.J. Onsrud, editors, *Diffusion and Use of Geographic Information Technologies.* Dordrecht: Kluwer Academic Publishers, pp. 165-194.

Rogerson, P. (1992) A nonparametric test for pattern detection and its use in GIS. *Proceedings, GIS/LIS* 2: 646-51.

Schimel, D.S., F.W. Davis, and G.T. Kittel (1993) Spatial information for extrapolation of canopy processes: examples from FIFE. In J.R. Ehleringer and C.B. Fields, editors, *Scaling Physiological Processes: Leaf to Globe*. New York: Academic Press, pp. 21-38.

Scott, J.M., F.W. Davis, B. Csuti, R. Noss, B.P. Buttenfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T.C. Edwards, J. Ulliman and R.G. Wright (1993) Gap analysis: a geographic approach to protection of biological diversity. *Wildlife Monographs* 123: 1-41.

Stine, P., F.W. Davis, B. Csuti, and J.M. Scott (in press) Conservation planning at different scales of investigation: a comparison of two mapping efforts in Southern California. *Symposium on Biodiversity in Managed Landscapes, Sacramento, CA, July 13-17, 1992.*

Tobler, W.R. (1993) Three Presentations on Geographical Analysis and Modeling. *NCGIA Technical Report 93-1*. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Weber, C., and M. Yuan (1993) Cartographic sonification: an analysis of subject association of harmonic intervals with various cartographic adjectives. *Proceedings, ACSM/ASPRS, New Orleans, LA, 1993*, 1: 391-400.

Xia, F. and A.S. Fotheringham (1993) Exploratory spatial data analysis with GIS. *Proceedings, GIS/LIS '93, Minneapolis, MN, November, 1993*, pp. 801-810.

Zektser, I.S., and H.A. Loaiciga (1993) Groundwater in the global hydrologic cycle. In Y. Eckstein and A. Zaporozec, editors, *Global and Regional Issues in Environmental Hydrology*. Water and Environment Federation, Alexandria, Virginia, pp. 177-180.

Zhan, F., and D.M. Mark (1993) Conflict resolution in map generalization: a cognitive study. *Proceedings, Auto Carto 11, Minneapolis, MN, October 1993, pp. 406-413*.

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

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

Beard, K., and W. Mackaness, Interaction in map design. *International Journal of Geographical Information Systems*.

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

Church, R.L., and R. Gerard, The generalized approach to modeling the hierarchical maximal covering location problem with referral. *Papers in Regional Science*.

Church, R.L., and R. Gerard, Closest assignment constraints and location models: properties and structure. *Location Science*.

Church, R.L., and R. Gerard, A general construct for the zonally constrained p-median problem. *Environment and Planning*.

Church, R.L., and A. Murray, Heuristic approaches to operational forest planning problems. *Spektrum*.

Church, R.L., and A. Murray, Constructing and selecting adjacency constraints. *INFOR*.

Cole, H. Sam, A spreadsheet approach to GISA, Association of Collegiate Schools of Planning, Columbus, Ohio. *Journal of Planning Education and Research.*

Dell, R.F., R. Batta, and M.H. Karwan, The multiple vehicle TSP with time windows and equity constraints over a multiple day horizon. *Transportation Science.*

Egenhofer, M., and R. Franzosa, On the equivalence of topological relations. *International Journal of Geographical Information Systems.*

Frank, S., A review of digital spatial data cataloging systems. *Photogrammetric Engineering and Remote Sensing*.

Freundschuh, S.M., Spatial knowledge acquisition of urban environments from maps and navigation experience. *The Professional Geographer*.

Freundschuh, S.M., and D.J. Mercer, Spatial cognitive representations of story worlds acquired from maps and narrative. *Journal of Memory and Language*.

Garling, T., M.-P. Kwan, and R.G. Golledge, Computational-process modelling of household activity scheduling. *Transportation Research*.

Gould, M.D., and P.J. Densham, Spatial decision support systems for environmental management: oil spill response. *Environmental Management*.

Hassen, K., and M.K. Beard, Reference grid: a technique for visualizing the effect of positional transformations with a GIS. *International Journal of Geographical Information Systems.*

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.*

Hunter, G.J., and M.F. Goodchild, Investigation of the effect of uncertainty in spatial databases upon slope gradient and aspect estimates. *Photogrammetric Engineering and Remote Sensing*.

Jin, H., and R. Batta, Modeling uncertainty in hazardous materials transportation. *Annals of Operations Research.*

Jin, H., R. Batta, and M.H. Karwan, On the analysis of two new models for transporting hazardous materials. *Operations Research.*

Mackaness, W.A., An algorithm for conflict identification and feature displacement in automated map generalization. *Cartography and Geographic Information Systems.*

Mark, D., and M. Egenhofer, Modeling spatial relations between lines and regions: combining formal mathematical models and human subjects testing. *Cartography and Geographic Information Systems.*

Paradis, J., and K. Beard, Data quality filter: a user's tool for data quality assessment. *Journal of the Urban and Regional Information Systems Association.*

Rogerson, P., Handedness and season of birth reconsidered. *Cortex.*

Sivakumar, R.A., and R. Batta, The variance-constrained shortest path problem. *Transportation Science.*

APPENDIX 2 - PRESENTATIONS BY NCGIA PERSONNEL

December 15-16: The NCGIA Workshop on Global Economic Modeling was held at the UN Church Center Plaza in New York (see Outreach section above). Buffalo Center members presenting included: In the session "Challenges for Global Modeling and GIS": Sam Cole (chair) and Mike Batty. In the session "Geographic Information Systems and their Potential Contribution to the Analysis of Global Issues": Mike Batty (chair) and Paul Densham. In the session "Ecological and Human Systems Modeling and Statistics": Ezra Zubrow (chair). In the session "Spatial Analysis and Computation": Sam Cole, Stewart Fotheringham and Pete Rogerson. In the Panel Session: "Conclusions for GIS Applications to Global Modeling": Mike Batty and Sam Cole. GIS Software was demonstrated by PhD students Yuemin Ding, Yichun Xie and Frank Xia. Waldo Tobler attended from Santa Barbara.

January 5-8: Paul Densham gave the invited paper "Spatial decision support for locational planning" at the Institute of British Geographers Annual Conference, Egham, Surrey, United Kingdom.

January 11: Michael Goodchild visited the U.S. Geological Survey, Washington DC, to discuss plans for the Breckenridge conference.

January: Frank Davis was a participant, International Workshop on Biodiversity Surveys, Inventories and Data Organization, Smithsonian Institution, Washington, DC.

January: Frank Davis was workshop organizer (with Mike Gilpin, Ted Case and Peter Brussard) and speaker, "Managing Natural Landscapes for the Conservation of Biodiversity", San Diego, California.

January 17: Michael Goodchild attended a meeting at CIESIN, Saginaw, MI, to discuss plans for a historical spatial database for China.

January: Mei-po Kwan, a graduate student working with Reg Golledge, attended the annual conference of the Transportation Research Board in Washington, DC.

January 22: Michael Goodchild attended a meeting of the NOAA Coastwatch accuracy assessment for change detection working group, North Carolina State University, Raleigh.

January 29: Michael Goodchild presented "The Spatial Perspective: Geographic Information in Contemporary Social Science" to the Jacob Marschak Interdisciplinary Colloquium on Mathematics in the Behavioral Sciences, UCLA.

January 30: A workshop was held at Clark University, Worcester, MA, to discuss spatial analysis functionality in IDRISI. Michael Goodchild participated from NCGIA.

February 5: Max Egenhofer presented "Spatial Relations in GIS: From a Formalization to Cognitive Studies" at the Center for Mapping, Ohio State University.

February 5: Michael Goodchild presented "Accuracy of Spatial Databases" and "GIS Research and NCGIA" at the University of Utah.

February 8-10: Stewart Fotheringham presented his work "GIS and spatial analysis: current issues" at the First Annual Sharjah conference on GIS, United Arab Emirates.

February 10: David Mark gave a talk entitled "Overview of National Center for Geographic Information and Analysis, University at Buffalo" at the Niagara Frontier Chapter of Association of Computing Technology.

February 13-17: David Tyler, Max Egenhofer, and students from the University of Maine student chapter of the ACSM attended the ACSM/ASPRS Annual Convention, New Orleans, LA. Egenhofer presented "Towards a Research Agenda for Spatio-Temporal Reasoning in GIS."

February: Frank Davis presented "Gap Analysis of Biodiversity in California" at the Bureau of Land Management, Sacramento, California.

February 15-16: Michael Goodchild gave the keynote address: "Accuracy Of Spatial Data: Problem Or Opportunity?" at a meeting organized by the Interagency Committee on Geomatics, Government of Canada, and a workshop "Accuracy of Spatial Data: Problem or Opportunity?" to the Ministry of Natural Resources, Province of Ontario, Toronto.

February 16-18: David Mark presented two papers at the ACSM/ASPRS annual meeting in New Orleans, Louisiana. They were: "Testing users' reactions to simulated system responses to queries involving spatial relations between lines and regions" (Max Egenhofer, co-author) and "On the possible role(s) of a 'University consortium for geographic information and analysis' (UCGIA)" (co-authored by the UCGIA steering committee).

February 16-18: PhD student May Yuan presented the paper she co-authored with David Mark "Spatiotemporal representation of wildfire in GISs" at the ACSM/ASPRS Annual Meeting, New Orleans, Louisiana.

February 16-18: PhD Students Chris Weber and May Yuan presented their paper "Cartographic sonification: an analysis of subject association of harmonic intervals with various cartographic adjectives" at the ACSM/ASPRS Annual Meeting, New Orleans, Louisiana.

February 16: Hugo Loaiciga presented "Hydrocarbon Contamination and Groundwater Remediation" to the Coast Geological Society, Ventura, CA.

February 18-21: Steven Frank attended the Federal Geographic Data Committee's National Spatial Data Infrastructure Specialists Meeting, Charleston, SC.

February 18-21: Sam Cole presented his paper "Towards a macro-economic policy model for China. Macroeconomic policy models from transition economy from centrally planned to socialist market" at the Development Research Center, State Council of People's Republic of China, Beijing.

February 19: Max Egenhofer presented "Database Requirements for Vehicle Navigation in Geographic Space" at the Remote Sensing and Image Processing Laboratory, Louisiana State University.

February 24-28: Stewart Fotheringham presented "GIS and exploratory spatial data analysis" at the NCGIA meeting on Exploratory Spatial Data Analysis, Santa Barbara, California. Other NCGIA presentations were made by Michael Goodchild, Luc Anselin, and Rusty Dodson.

March: Sam Cole presented a paper "Community Accounting for Economic Development" at the University of Michigan Forum on Critical Issues.

March 7-10: Steven Frank, Barbara Bicking, Jennifer Sanborn, Tony Sleezer, and Langley Willauer, graduate students in the Department of Surveying Engineering and the NCGIA, attended the GIS in Business '93 Conference, Boston, MA.

March 9-10: David Mark was the keynote speaker at the Federal Spatial Features Forum, US Geological Survey, Reston, VA.

March 11: Kate Beard attended the New England Regional AM/FM Conference, Boston, MA, and presented "NCGIA and the Education Response".

March 9-12: Richard Church (with Alan Murray) spoke on "Adjacency constraint aggregation" at the International Symposium on Systems Analysis and Management Decisions in Forestry in Valdivia, Chile.

March 14: Hugo Loaiciga spoke on "Impacts of GIS on Organizations" at the Spring Symposium on Geographic Information Systems and Water Resources, American Water Resource Association, Mobile, Alabama.

March: Steve Palladino made a GIS presentation for high school students at Oxnard Community College as part of their annual Geography Bowl for local high schools.

March 18-20: Stewart Fotheringham attended the First National Conference on GIS Research, UK, and participated in a panel discussion on "GIS Research Agenda, The Critical Issues".

March 25-26: Mike Batty traveled to Philadelphia to visit the Department of City and Regional Planning, University of Pennsylvania.

March 26: Mike Batty visited the University of Pennsylvania Program in Real Estate and Land Development, and presented a lecture entitled "Fractal Cities".

March 28 - 29: Michael Goodchild attended a "Workshop on accuracy assessment" for Coastwatch, NOAA, Berkeley CA.

March 29: Jayant Sharma presented "Topological Relations" at a University of Maine Department of Computer Science Seminar.

April 5-9: Jeff Star chaired a session as part of the wind-up of I12 at the Twenty Fifth Remote Sensing of the Environment Conference, in Graz, Austria. Jack Estes discussed the methods used to establish priorities for the near term research in the Integration of Remote Sensing and GIS. After Estes' talk, Manfred Ehlers of the University of Osnabruch in Vechta, Germany, and formerly a University of Maine participant for I12, urged an improved data collection. James Lawless of NASA Headquarters for Mission to Planet Earth said that there were important unsolved problems hindering the agency's mission. John MacDonald, Chairman of MacDonald Dettwiler in British Columbia, spoke for the private sector: he hoped for a better understanding of the measure process with GIS; noted there was insufficient knowledge of the earth's surface shape; and stated that there is a need for better feature extraction technologies.

April 5-11: Several NCGIA researchers attended the 1993 Annual Meeting of the Association of American Geographers, Atlanta, GA. Egenhofer presented "The Conceptual Neighborhood of Topological Relations between Regions and Lines" and Flewelling presented "Can Cartographic Operations be Isolated From Geographic Space?". David Mark chaired two sessions: "Application of GIS to Global Change and Assessment" and "Environmental Perception and Behavioral Geography & Cartography Specialty Groups: Research in Navigation and Wayfinding", and also contributed the papers "Relations between human judgments of spatial relations and topological models of those relations" and "Potential role of GIS in global change research" (co-authored with Dennis Jelinski). Barbara Buttenfield presented "Prototype Hypermedia Tools for GIS Queries and Models" with PhD student Chris Weber. The paper "Parallel Construction of

Delaunay Triangulations" co-authored by Paul Densham and PhD student Yumin Ding was presented, and Paul Densham served as organizer, chair and panelist in a panel session entitled "Spatial Decision Support Systems: a Review and Future Directions" and as Chair of a session entitled "GIS Modeling and Algorithm Development". Other Buffalo researchers attending the AAG included Sam Cole, Dennis Jelinski, Stewart Fotheringham, Andrew Curtis (PhD student), and Richard Weng (PhD student). Mr. Weng's contribution was entitled "The Exchange Behavior within US Families: A Financial Relationship." Mei-po Kwan, Reg Golledge and Tommy Garling (U. of Goteborg, Sweden) presented the paper "Computational-Process Modelling of Travel Decisions Using a GIS". Michael Goodchild chaired a session and presented a paper in the I6 Spatial Decision Support System session. Reg Golledge presented "Survey Versus Route-Based Wayfinding in Unfamiliar Environments".

April 11-12: Michael Goodchild visited Iowa State University, Ames, and gave the keynote presentation at the Iowa State GIS conference, and also met with University administrators.

April 12-13: Mike Batty visited NCGIA at Santa Barbara for discussions with Helen Couclelis, Bob Barr and Mike Goodchild.

April 14-16: Mike Batty attended the Fourth International Workshop on Technological Change and Urban Form: Productive and Sustainable Cities, University of California at Berkeley. He presented the paper "Cities and Complexity: The Implications for Modeling Sustainability" (co-authored by Sam Cole and PhD student Frank Xia).

April 15-16: Michael Goodchild attended the North Carolina GIS Conference, Raleigh, and gave the keynote presentation.

April 19: Michael Goodchild attended the On Common Ground Conference, Denver to present a paper, "Issues in integrating the spatial data technologies."

April 23: Michael Goodchild attended New York University to present a paper on "GIS Research and NCGIA."

April 29: Michael Goodchild visited Lockheed Corp, Palo Alto to present a paper on "GIS Research and NCGIA."

May 1-5: Mike Batty attended the APA National Planning Conference in Chicago. He presented his work "A Chronicle of Scientific Planning: The Anglo-American Modeling Experience".

May 3-6: Hugo Loaiciga gave a presentation (with I.S. Zektser): "Global groundwater cycle and greenhouse warming" at the 20th Annual Conference of the Water Resources Planning and Management Division, ASCE, Seattle, Washington. He also chaired the technical session on "Global warming and hydrologic variability".

May 3-9: Barbara Buttenfield presented a paper (co-authored with Geoffrey Dutton) "Scale change via hierarchical coarsening: cartographic properties of quaternary triangular meshes" at the 16th International Cartographic Conference, Cologne, Germany.

May 3-9: William Mackaness attended the 16th International Cartographic Conference, Cologne, Germany, and presented "Graph Theory and Map Generalization". He also presented "Events and Episodes: Patterns in Time" at the ICA Working Group on Temporal Issues in GIS special two-day symposium at Delft University.

May 5: Paul Densham visited NYNEX Science and Technology in White Plains, NY, to discuss applications of location-allocation models and spatial decision support systems in the optimization of telecommunications networks and to present the paper "Design and Implementation of Spatial Decision Support Systems for Network Optimization Problems".

May 7-8: Michael Goodchild visited FORMEZ, Naples, Italy to present lectures on GIS.

May 8-12: Harlan Onsrud attended the National Geodata Policy Forum, Washington, DC, and moderated a session. Michael Goodchild was a panelist in the closing session. Hugh Calkins attended the forum from Buffalo.

May 8-11: The following UCSB/NCGIA members attended the I10 Specialist Meeting (Temporal Issues and GIS) at Lake Arrowhead, California: Helen Couclelis, Waldo Tobler, Dan Montello (faculty); Tom Cova, Mei Po Kwan, Scott Bell (graduate students), Judith Parker (staff).

May 10: David Tyler and Max Egenhofer attended a planning meeting of the Maine Science and Technology Commission on defense technology conversion, Augusta, ME.

May 15-20: Hugh Calkins and Ph.D. Student Rick Weatherbe traveled to Orlando, FL to conduct research and gather case studies on Spatial Data Sharing (I9) in Orlando and Orange County.

May 16-21: Hugo Loaiciga gave a presentation (with I.S. Zektser): "Groundwater flow in the global hydrologic cycles: past, present and future" at the Second USA/CIT Joint Conference on Environmental Hydrology and Hydrogeoology, Washington D.C.

May 16-19: Center Member and Interim Chair of Industrial Engineering, Rajan Batta, and his advisee, PhD student Amitabh Bansal, attended the TIMS/ORSA conference in Chicago. A paper they had co-authored, "Theoretical Analysis of Data Aggregation Effects on Location Problems" was presented at the conference. Dr. Batta also presented a paper he had co-authored with M.H. Karwan, Professor of Industrial Engineering, "Hazardous Materials Routing: A Probabilistic Perspective."

May 17-19: Kate Beard presented a three-day GIS workshop for University of Maine faculty and graduate students.

May 18: Ezra Zubrow gave the invited paper "Ancestry, Progeny and Kin: The Demographic Evolution of the Prehistoric Family" at the Department of Biological Anthropology, Cambridge University, Cambridge, UK.

May 20-21: Mike Batty visited the University of Bristol and Academic Press, London to discuss publications.

May 22-24: Mike Batty attended the workshop Urban and Regional Planning: Advances in Method and Technology at the Faculty of Land Surveying and Rural Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece. His presentation was entitled "Planning support systems and the new logic of computation".

May 22-24: Max Egenhofer visited Intergraph Corp., Huntsville, AL, and presented "GIS User Interfaces and Spatial Reasoning".

May 23-28: Kate Beard, Kathleen Hornsby, and Sarah Clapham from Maine attended the 13th Annual ESRI User Conference, Palm Springs, CA. Michael Goodchild, Steven Palladino, Karen Beardsley, Jonathan Baldwin, Judith Parker, and a group of graduate and undergraduate students attended from Santa Barbara.

May 25: Michael Goodchild visited the University of California, Riverside, and gave a guest lecture to the Department of Statistics.

May 25-28: Max Egenhofer attended the 1993 ACM SIGMOD Conference, Washington, DC, and presented "What's Special about Spatial - Database Requirements for Vehicle Navigation in Geographic Space".

May 26: Mike Batty visited Nicos Polydorides, Director of the National Information Documentation Center, and Editor of the URSA-Net, Athens, Greece.

May 26: Ezra Zubrow presented his paper "Prehistoric Progeny" at the Department of Archaeology, University of Leicester, Leicester, UK.

May 27: Max Egenhofer visited Intergraph Corp., Reston, VA, and presented "Trends in GIS Research".

June 1993: Sam Cole presented the paper "Cultural Accounting in the Caribbean" at the Western Economic Association International 68th Annual Conference in Lake Tahoe.

June 1993: Rajan Batta presented a paper entitled "Theoretical Analysis of Data Aggregation Effects on Location Problems", at the Conference on Applied Probability in Engineering, Computer and Communication Sciences in Paris. This work was co-authored by Dr. Batta with M. Jamil and D.M. Malon.

June 1993: Ezra Zubrow participated in the British Calendrical and Cosmological Society Meetings, Stromness, Orkney, UK.

June 1993: Munroe Eagles gave an Invited Paper: "Money and Votes in Canada," at the Special Session on "Empirical Political Economy" at the Canadian Economics Association, Ottawa, Ontario.

June 6-8: Michael Goodchild attended the National Science Foundation workshop on technical design for a proposed National Center for Synthesis in Environmental Biology,

June 14-16: Max Egenhofer attended the International Workshop on an Infrastructure for Temporal Databases, Arlington, TX, and presented "What's so Tough About Time and Space."

June 17-18: Jack Loomis (UCSB Psychology), Reg Golledge, and Bobby Klatzky (UCSB Psychology) presented "Personal guidance system for the visually impaired using GPS, GIS, and VR technologies," at the Conference on Virtual Reality and Persons with Disabilities, San Francisco.

June 17: Ezra Zubrow gave the invited paper "Unfolding Space: Whither Archaeology" at the Department of Archaeology, Cambridge University, Cambridge, UK.

June 18-25: Max Egenhofer and Jayant Sharma attended the Third International Symposium on Large Spatial Databases, Singapore. Egenhofer held an invited tutorial on "Spatial Query Languages for GIS" and presented "Topological Relations between Regions in R^2 and Z^2" (M.J. Egenhofer and J. Sharma, authors).

June 21-25: David Tyler attended the Global Positioning Systems/Geographic Information Systems Third International Conference, Seattle, WA, and presented "Integrating Spatial Data Technologies".

June 28-July 3: Paul Densham and Michael Goodchild attended a conference on "Spatial Analysis in ARC/INFO", Lancaster University, UK, June 28-30. Densham presented the paper "Decision Support Systems and Facility Location Problems in ARC/INFO", and then visited the University of Bristol, July 2-3 to discuss

possible research ties with the NCGIA on locational analysis. Michael Goodchild acted as a discussant, and later visited the University of Salford to discuss distance learning and the UNIGIS consortium, and the University of Leicester to discuss possible publications.

July 1-31: Max Egenhofer was a visiting scientist at the Université di L'Aquila, Italy.

July 6-8: Michael Goodchild participated in a workshop on accuracy assessment for Coastwatch, NOAA, Ocean City, MD

July 7-9: PhD students Michael Leitner and Marcus Wieshofer attended the International Symposium for Applied Geographic Information and Technology (AGIT), Salzburg, Austria. They presented their co-authored paper: "Education and Research in GIS and Computer Cartography at the Department of Geography at SUNY/Buffalo".

July 11-14: Reg Golledge presented "Time and space in route preference," at the Thirteenth Meeting of the Pacific Regional Science Conference Organization and Seventeenth Annual Meeting of the Canadian Regional Science Association.

July 12: Michael Goodchild visited Simon Fraser University, Burnaby, BC, to serve as an external examiner for a PhD candidate.

July 14-16: Michael Goodchild visited the United Nations Environment Program, Nairobi, Kenya, where he presented a paper on "Sharing Imperfect Data", and chaired sessions.

July 19-25: Mike Batty traveled to Tennessee and Georgia and visited the following sites: Oak Ridge National Labs, - to present the paper "Urban Location Models in ARC-INFO" and discuss the subject of location and transportation modeling within GIS with colleagues there; the University of Tennessee GIS Laboratory in Knoxville, TN - where he was treated to demos of various projects relating to transport and GIS; Georgia Institute of Technology, Atlanta, GA - PhD Student Yichun Xie and Mike Batty attended the Third International Conference on Computers in Urban Planning and Urban Management. Mike Batty was a co-organizer of the last meeting, and Mike and Yichun presented their co-authored papers: Modeling inside GIS: Part 1: Model Structures and Interactive Graphics, and Modeling inside GIS: Part 2: Urban Location Models Using ARC-INFO, and Mike also presented his work: "A Chronicle of Scientific Planning". He also attended the URISA workshop "Introduction to Small Area Forecasting: Implementation, Connections to GIS, Planning and Policy in the 1990s," held in Atlanta on July 25th 1993- where he presented a session on "Future Development of Links between Small Area Forecasting Models and GIS". This paper was printed in the associated workbook for the meeting.

July 23-25: Hugh Calkins attended the National Spatial Data Infrastructure meeting in Atlanta, GA.

July 25-29, Harlan Onsrud and Jeff Pinto attended the Urban and Regional Information Systems Association 1993 Meeting, Atlanta, GA. Gary Hunter and Michael Goodchild presented "Managing uncertainty in spatial databases".

July 26: Hugo Loaiciga presented "Groundwater contamination protection and remediation in Latin America" as a keynote lecture at the SCOPE/UNEP Regional Groundwater Workshop for Latin America in San Jose, Costa Rica.

August: Gary Hunter and Michael Goodchild presented "New technological trends: visualizing uncertainty in spatial databases" at the AURISA '93 conference, Adelaide, South Australia.

August: Sam Cole chaired the session "Time Bombs of Our Time" at the World Futures Federation XIII World Conference on Coherence and Chaos in our Uncommon Futures, Turku, Finland.

August 19-20: David Mark visited NCGIA-Maine to discuss research projects with Max Egenhofer.

August 24-25: David Tyler met with Atlantic Institute and CERCO representatives, Quebec City, Canada, and presented "The NCGIA Research Program."

Sept. 1993: Sam Cole attended the workshop on "Methods and Tools in Strategic Perspective: A Retrospective on 25 Years of Research" at the European Joint-Research Center, Ispra, Italy with the intent of forming a European based professional futures group.

Sept. 1993: Babs Buttenfield gave an invited lecture at USGS National Mapping Division's Fortnightly Seminar Series, Reston, VA on Roles for Multimedia in GIS.

Sept. 2-11: Mike Batty met with publishers in London and Bristol to discuss publication of research works.

Sept. 12-16: Mike Batty and Stewart Fotheringham attended the 8th Theoretical and Quantitative Geographic Colloquium, Budapest, Hungary. Stewart presented a paper entitled: "Location-Allocation Modeling and the Zone Definition problem". Mike Batty presented the work he co-authored with V. Mesev, P. Longley and Y. Xie, "Fractal Analysis of a Classified Urban Image: The Case of Bristol, UK."

Sept. 16-17: Paul Densham visited the University of Iowa to discuss potential I17 research with Dr. Marc Armstrong. He also delivered the address "Using Parallel Processing to Extend the Modelbase Management System of a Spatial Decision Support System for Location Selection" at The University of Iowa's Department of Geography Colloquium Series.

Sept. 17-19: David Mark attended the Workshop on "Formalizing Spatial Relations" in Mariana Marina, Elba, Italy and presented his research. Max Egenhofer was co-chair of the workshop.

Sept. 20-22: David Mark participated in, and served as North American Co-Chair for, the Conference on Spatial Information Theory (COSIT '93) in Elba, Italy. David made remarks in the opening session, chaired a panel, and presented the paper "Cultural Differences in Spatial Cognition: Toward a Theoretical Framework for Geographic Entity Types". Max Egenhofer attended and presented "Interaction with GIS Attribute Data Based on Categorical Coverages" (co-author Gary Volta) and chaired a panel on "What's in, What's out?"

September 26-29, Luc Anselin attended the Second International Conference on Integrating Geographic Information Systems and Environmental Modeling, Breckenridge, CO, and presented a tutorial on "Exploratory spatial data analysis". Barbara Buttenfield gave an invited presentation on scientific visualization.

Oct. 1993: Sam Cole attended the principal investigators meeting of the National Center for Earthquake Engineering Research (NCEER), SUNY at Buffalo and presented the work that he and others are carrying out in Buffalo's East Side neighborhoods, South Dade County and the Caribbean.

Oct. 1993: Rick Church presented Location Modeling and GIS, at the Japan GIS Association meeting.

Oct. 7-15: Hugh Calkins met with Ian Masser and Heather Campbell, Department of Town and Regional Planning, The University of Sheffield, Sheffield, UK, to discuss research on Institutions Sharing Data. He then visited Dr. Jonathan Raper, Dept. of Geography, University College London to discuss research on 3-D GIS and water quality models.

Oct. 13: Mike Batty and Sam Cole visited Dr. Mark Salling, Cleveland State University to continue discussions about a collaborative effort between NCGIA-Buffalo and the College of Urban Affairs of Cleveland State University, and develop a proposal for submission to the Visiting Fellows Program of the NCGIA.

Oct. 13: Paul Densham visited Professors Joe Ferrera and Britton Harris at MIT to develop a proposal for submission to the Visiting Fellows Program of the NCGIA, for collaboration on the NCGIA Research Initiative "Collaborative Spatial Decision-Making".

Oct. 14-15: Mike Batty visited the Regional Science Research Institute at the University of West Virginia, Morgantown, WV and presented a paper on "Modeling and GIS".

Oct. 14-15: Paul Densham attended the 16th Annual Applied Geography Conference at Ryerson Polytechnic Institute, Toronto and presented the paper "A Spatial Decision Support System for Optimizing Retail Bank Networks".

Oct. 15-17: Munroe Eagles presented the paper: "The Study of Canadian Electoral Behavior: A Comment on Approaches and Methods" at the Atlantic Provinces Political Studies Association annual conference, St. Francis Xavier University, Antigonish, Nova Scotia, Canada.

October 18-20: William Mackaness attended the 8th Annual Northeast ARC/INFO Users Group Conference (NEARC), Burlington, VT, and presented "A Summer Workshop: GIS in Secondary Schools".

Oct. 19-Oct 22: Mike Batty presented the paper "Models of Urban Structure: Applications Using Computer Graphics and GIS" at the Simposio Sistemas Metropolitanos, El Colegio, Mexiquense, Mexico.

October 24-27: Michael Collins and William Mackaness attended the I8 Specialist meeting, Buffalo, NY. Two papers were presented by Mackaness and Collins: "The Cognitive Ergonomics of Computer Assisted Visualization Design" (A.G. Turk and W.A. Mackaness, authors); and "On the Abstraction of Cartographic Objects from Remotely Sensed Imagery" (M.J. Collins and W.A. Mackaness, authors).

Oct 24-28: Mike Batty presented a paper entitled "Planning Support Systems and the New Logic of Computation" at the United Nations Conference on Regional Development seminar on Planning Support Systems for Local and Regional Development, Cebu City, Philippines (Oct. 24-28); and gave an invited presentation to the Chinese Regional Science Association, Taipei, Taiwan (Oct. 28-November 1).

October 27-31: Harlan Onsrud attended the first European Science Foundation GISDATA Specialist Meeting, Knutsford, England. He presented a paper co-authored by fourteen U.S. researchers, "Experiences in Acquisition, Implementation, and Use of GIS in U.S. Local Governments: A Sampler of Academic Studies and Findings".

Oct. 28-29: PhD Student Yichun Xie substituted for Mike Batty as discussant in the Sessions "Requiem for Large-Scale Models" and Communication in Urban Design" at the 35th Annual Meeting of the Association of Collegiate Schools of Planning, Philadelphia, PA.

Oct 28-November 1: Mike Batty visited the Center for Building and Planning at the National University of Taiwan, Taipei, as a guest of the Chinese Regional Science Association. He also visited the Hsunchu Science Park and presented a paper entitled "GIS, Urban Models and Metropolitan Urban Structure".

October 30-November 1: Kate Beard, Max Egenhofer, Doug Flewelling, and William Mackaness attended Auto-Carto 11, Minneapolis, MN. Mackaness presented "Visualization of Interpolation Accuracy" (W. Mackaness and K. Beard, authors). Egenhofer presented, "The Geographer's Desktop: A Direct-Manipulation User Interface For Map Overlay" and Flewelling presented "Formalizing Importance: Parameters For Settlement Selection From A Geographic Database."

November: Rick Church and A. Murray presented "Heuristic Approaches for Solving Area-Based Forest Planning Problems" at the ORSA/TIMS Meeting, Phoenix, AZ. Rick Church and R. Gerrard presented "An Improved Formultation for the Location Covering with Thresholds".

November 1: David Mark was one of four co-organizers of a meeting to discuss the merits and possible organization of a "University Consortium for Geographic Information and Analysis". Results of the discussion were reported in a Panel Session at GIS/LIS.

Oct. 30-November 4: The Auto-Carto 11 (Oct. 30-November 1) and GIS//LIS (Nov 2-4) conferences in Minneapolis were attended by a large number of NCGIA-Buffalo affiliates, including David Mark, Paul Densham, Hugh Calkins, Babs Buttenfield and PhD Students Catherine Dibble and Yichun Xie. I8 Steering Committee members Peter Fisher, Rob Weibel and Geoffrey Dutton, and Roberta Lenczowski joined Barbara Buttenfield in presenting outcomes from the recently concluded Specialists Meeting in the session "Formalizing Cartographic Knowledge: Research Priorities". Barbara Buttenfield chaired the Session "Multimedia and GIS in Industry" and co-chaired (with Kate Beard) the NCGIA Visualization Challenge. Hugh Calkins and Rick Weatherbe's co-authored paper: "Case Studies of Spatial Data Sharing" which detailed some of the outcomes of I9 research was presented at the meeting. Also presented was the paper "GIS Based 3-D Segmentation for Water Quality Modeling", co-authored by W. Guan, Frank Xia and Hugh Calkins, presenting research done in cooperation with the Great Lakes Program at SUNY Buffalo. Paul Densham presented his work "Integrating GIS and Parallel Processing to Provide Decision Support for Hierarchical Location Selection Problems". Paul was also a joint presenter of a workshop with P.F. Fisher, entitled "Introduction to Spatial Analysis with GIS". David Mark participated in the session "The University Consortium for Geographic Information an Analysis (UCGIA): Proposal and Prospects, to report the outcomes of the discussions held at the November 1 UCGIA meeting. He also presented the paper "Theoretical Framework for Extending Entity Types in SDTS". PhD student May Yuan's paper "Integrating Objects and Layers in GIS for Wildland Fires" (co-authored with Yue Hong Chou, UC-Riverside) was presented. PhD student Catherine Dibble presented the paper she co-authored with Paul Densham, "Generating interesting alternatives in GIS and SDSS using genetic algorithms". David Mark served as a member of the Program Committee for Auto Carto 11. In addition, he presented the paper he co-authored with Max Egenhofer and Jayant Sharma of the University of Maine "A Critical Comparison of the 4-Intersection and 9-Intersection Models for Spatial Relations: Formal Analysis". Paul Densham served as Chair of a special session entitled "Terrain Representation" and presented the paper "Supporting Visual Interactive Locational Analysis using Multiple Abstracted Topological Structures". Barbara Buttenfield also participated in Auto-Carto 11. Kate Beard, William Mackaness, and Harlan Onsrud attended GIS/LIS '93 from Maine. Beard organized a session for presentation of the Visualization Challenge final results.

November 1993: Sam Cole participated in a United Nations Fund for Population Activities (UNFPA) Round Table on Population and Development Strategies in Bangkok, Thailand in preparation for the 1994 International Conference to be held in Cairo, Egypt.

November 9-11: Ezra Zubrow gave the invited papers "Temporal GIS: Problems for the Historical and Prehistoric Sciences", "The Application of GIS to Archaeology: Case Studies" and the workshop "Studying Archeology in the United States" at the GIS-paivat, University of Helsinki, Helsinki, Finland. In addition he presented the paper "Reflections of the Past: The State of American Archaeology" at the Department of

Archaeology at the University of Helsinki and also at the University of Turku, Turku, Finland on November 16.

November 10-12: Stewart Fotheringham attended the North American Regional Science Association Meeting in Houston, Texas. He presented the paper "Location-Allocation Modeling and the Zone Definition Problem" in the session he chaired and organized "Spatial Analysis and the Definition of Zonal Units". Sam Cole presented two papers at the meeting. R. Gerrard and Rick Church presented "Closest Assignment Constraints in Linear Formulations of Facility Location Problems". A. Murray and Rick Church presented "Simulated Annealing as a Solution Methodology for Location Models". O.B. Schoeplfe and Rick Church presented "A Districting Application of the Multi-Resource Bounded-Interval Generalzied Assignment Problem". Luc Anselin also attended the meetings, and presented "Spatial dependence in regression analysis: A review and reassessment.

November 11-14: David Mark, Helen Couclelis, Harlan Onsrud, and graduate students Buddy Dowdy and Catherine Dibble participated in the NCGIA Workshop on Geographic Information and Society in Friday Harbor, Washington.

November 15, Kate Beard, Kathleen Hornsby, William Mackaness, and Tony Sleezer attended the Integrating Spatial Information Technology: Using Geographic Information Systems in the Planning and Decision-Making Process conference, South Portland, ME. Beard presented "How Does GIS Affect the University Curriculum?"

November 17: David Mark gave a talk entitled "Spatial Cognition & GIS" to about 60 people at the University of Waterloo, Ontario. He preceded his lecture with a 30 minute overview of the NCGIA.

November 18-20: Luc Anselin attended the DOSES/Eurostat Workshop on New Tools for Spatial Analysis, ISEGI, Lisbon, Portugal, and gave a paper on "Exploratory spatial data analysis and geographic information systems".

November 26: David Mark visited the Centre for Geographical Information Processing, Wageningen Agricultural University, Wageningen, Netherlands, and gave a lecture about the NCGIA, and another about his research on spatial relations.

November 29-Dec. 3: David Mark was an invited participant in a 5 day workshop entitled "Multiple Worlds: A Conference on Spatial Relations", hosted by the Cognitive Anthropology Research Group of the Max Planck Institute for Psycholinguistics, Nijmegen, the Netherlands.

November 30-Dec. 1: Mike Batty visited the Graduate School of Architecture and Urban Planning at UCLA and presented a seminar entitled "Linking Models of Urban Structure to GIS".

APPENDIX 3 - VISITORS TO NCGIA SITES

Connie Adams, County of Santa Barbara
William Adler, President of PHH FleetAmerica
Mohammed Al Dada, Sharjah Municipality
Thomas Allen, Portland, ME, gubernatorial candidate for Governor of Maine
T.A. Arentze, Faculty of Architecture, Eindhoven University of Technology, Eindhoven, Netherlands
Marc Armstrong, Departments of Geography & Computer Science, University of Iowa
Warren Baker, National Science Board and Cal Poly San Luis Obispo
Earl Bamford, University of Adelaide, Australia
Robert Barr, University of Manchester, UK
Joe Basil, AR3, Orchard Park, NY
Alberta Bianchin, Department of Urban Planning, University of Venice, Italy
Greg Biging, UC Berkeley
Jan Terje Bjørke, Norwegian Institute of Technology
Carsten Bjornsson, Royal Veterinary and Agricultural University, Copenhagen, Denmark
Lars Bodum, Department of Development and Planning, Aalborg University, Aalborg, Denmark
Valentina Boytcheva, Bulgarian Academy of Sciences
Steve Brandt, Department of Biology, SUNY at Buffalo
David Breiniger, Kennedy Space Center
Brian Bresolin, Santa Barbara Co. Assn. of Governments
Kate Brewin, Computer Science Editor, Academic Press, London
Mark Bright, County of Santa Barbara Resource Management
George Brown, U.S. Congress
Dieter Busch, U.S. Fish and Wildlife Service
Kevin Callaway, Port Hueneme High School, Oxnard, CA
Malcolm Campbell, Dos Pueblos High School, Goleta, CA
Jeff Carmody, Air Pollution Control District, Goleta, CA
David Casciotti, Planning Director, City of Buffalo
Neil Chisholm, University of Aberystwyth, Wales
Nick Chrisman, University of Washington
Ric Cicone, CIESIN
Ferko Csillag, Department of Geography, Syracuse University
Robert Currie, BC Institute of Technology
Joe DeLotto, NYNEX
Robert Earl, Erie County Legislature, NY
Deborah Elliot-Fisk, UC Office of the President
Pip Forer, University of Canterbury, New Zealand
Pierre Frankhauser, Institute for Research and Analysis of Economic and Spatial Dynamics (IRADES)
David Friedlander, Air Pollution Control District, Goleta, CA
George Friedman, American University
Jamie Furlong, Santa Ynez High and Refugio Continuation, Santa Ynez, CA
Ramez Gerges, Caltrans
Gary Gettings, Lompoc High School, Lompoc, CA
Kenn Glenn, Santa Barbara Municipal Transportation District
Michael Gould, Departamento de Geografia Humana, Universidad Complutense de Madrid, Spain
Brian Grassis, Erie County Water Authority, NY
William R. Greiner, President, SUNY at Buffalo
David J. Grimshaw, Lecturer in Information Management, Warwick Business School, Coventry, UK
Britton Harris, Department of City and Regional Planning, University of Pennsylvania.

Peter Haynes, President, Consumers Water Company, Portland, ME
Bill Hazelton, University of Melbourne, Australia
Ruth Hildenberger, Mitre
Stephen Hirsch, Mitre
Derek Hols, Council for Scientific and Industrial Research, Pretoria, South Africa
Gary Hunter, University of Melbourne, Australia
Rudolph Husar, Washington University, St. Louis, MO
Frederick Hutchinson, President, University of Maine
Tadashi Ikeda, Hitachi America Ltd., Tarrytown, NY
Edward Irvin, Jr, Lockheed
D. Bruce Johnstone, Chancellor, State University of New York, Albany
Erland Jungert, National Defense Research Establishment, Sweden
Peter Keller, University of Victoria
Marcia Kerchner, Mitre
Steven Kilston, Lockheed
Nicholas King, Divison of Water Technology, CSIR, South Africa
Keith Kirby, Harkness Foundation, New York
Brian Klinkenberg, University of British Columbia
D. Michael Landi, Vice President for Research, SUNY at Buffalo
Phil Langley, Langley Associates
Mark Leipnik, Bureau of Reclamation
Hai Lin, National Natural Science Foundation of China
Donna Lucas, Buena High School, Ventura, CA
Tom Lynch, University of Maine President's Development Council
Ross D. MacKinnon, Dean, Faculty of Social Sciences, SUNY at Buffalo
Bernhard Manerhof, Arnimatr, Munich, Germany
Bob Martin, Western New York Technology Development Center
Shin-Pei Matsuda, Hatachi Ltd, Tokyo
Koji Matsuoka, School of Management, Science University of Tokyo, Kuki City, Japan
Lois McCoy, National Institute for Urban Search and Rescue
Andrew McNeally, University of Maine
Frank Melcher, Free University, Berlin, Germany
T. Victor Mesev, Department of Geography, Bristol University
Ray Missert, Consultant
Wayne Mooneyhan, Universities Space Research Association
Alan Moore, Antarctic Research Associates
Terry Moore, City of Santa Barbara
Peter Newsom, AR3, Orchard Park, NY
Sue Ortega, Oxnard High School, Oxnard, CA
Kuninori Otsubo, National Institute for Enviornmental Studies, Environment Agency of Japan
Yorgos Papageorgiou, McMaster University, Ontario
Ronald Paulson, Lockheed
James Paw, International Center for Living Aquatic Resources Management, Manila, Philippines
Stew Penny, AR3, Orchard Park, NY
Ognian Pishev, Ambassador of the Republic of Bulgaria
Michael Powers, Santa Barbara Co. Assn. of Governments
Lee Ready, Western Washington University
Mark Reinhard, Martin, Northast & Spencer, Inc., Santa Barbara
Michel Rheault, University of Sherbrooke, Sherbrooke, Quebec
Michael Ridland, CSU Long Beach
Tom Riemenschneider, Deputy Dean of the Medical School, UB

Casey Roberts, Carpinteria High School, Carpinteria, CA
George Saikalis, Research & Development, Hitachi America, Farmington Hills, Michigan
Mark Salling, College of Urban Affairs, Cleveland State University
Nancy Salveggio, SUNY ESF, Syracuse, NY
David Sanchez, Santa Barbara High School
Joe Sarsenski, IBM
Ieda Seguira, United Nations, New York
Eva Sikierska, Department of Energy, Mines and Resources, Canada
Steve Stead, University of Leicester, UK
Rick Steinheiser, Research and Development, Central Intelligence Agency, Washington DC
Janine Stenback, California Dept of Forestry & Fire Protection
K. Stewart, Department of Biology, SUNY at Buffalo
Anne Tait, UK Consultant
Greg Theisen, NYNEX
Shelby Tilford, NASA, Washington, DC
Tim Traylor, Memphis State University
Alex Tuyahov, NASA
Peter van Demark
Jan van Wagtendonk, Yosemite National Park
Stephen Walsh, Spatial Analysis Labs, Department of Geography, University of North Carolina
Sharon Waltman, Cartographer, USDA Soil Conservation Service
Richard Welling, National Systems and Research Co
Newman Whitmire, Cabrillo High School, Lompoc
Rick Wood, Magellan Geographix, Santa Barbara, CA
Mike Worboys, Keele University, UK
Pan Xiang, Research Institute for Urban Planning and Design, Tongji University, Shanghai
Yong-Jian Zheng, Institute for Photogrammetry and Remote Sensing, Karlsruhe

APPENDIX 4 - COURSES TAUGHT BY NCGIA FACULTY

1. Santa Barbara

Urban Geography, Fall 1993, Helen Couclelis
Environmental Hydrology, Fall 1993, Hugh Loaiciga
Intermediate Remote Sensing, Fall 1993, Leal Mertes
History of Cartography, Fall 1993, Waldo Tobler
Special Topic Cartography, Fall 1993, Waldo Tobler
Environmental Perception and Cognation, Fall 1993, Dan Montello
Introduction Geography Information Systems, Fall 1993, Michael Goodchild
Introduction to Carto Programming, Fall 1993, David Lanter
Issues in Planning, Fall 1993, Richard Church
Digital Tech Remote Sensing, Fall 1993, Leal Mertes
Geographic Remote Sensing Techniques, Winter 1993, Leal Mertes
Introduction to Cartography, Winter 1993, David Lanter
Spatial Decisions in Retailing, Winter 1993, Michael Goodchild
Advanced Geographic Data Analysis, Winter 1993, Dan Montello
Technical Issues in Geographic Information Systems, Winter 1993, Terry Smith
Seminar in Cartography, Winter 1993, Waldo Tobler
Mathematical Models in Human Geography, Winter 1993, Dan Montello
Socioeconomic Geography, Spring 1993, Daniel Montello
Water and the West, Spring 1993, Richard Church and Hugo Loaiciga
Production Cartography, Spring 1993, David Lanter
Water Pollution, Spring 1993, Hugo Loaiciga
GIS Applications, Spring 1993, Michael Goodchild
Issues in Planning, Spring 1993, Richard Church
Seminar in Geography, Spring 1993, Daniel Montello
Seminar in Regional Analysis, Spring 1993, Luc Anselin
Seminar in Remote Sensing, Spring 1993, John E. Estes
Special Topics, Spring 1993, Reginald Golledge

2. Maine

Remote Sensing, Fall 1993, Michael Collins
Engineering Databases, Fall 1993, Max Egenhofer
Computer Law, Fall 1993, Harlan Onsrud
Research Methodologies, Fall 1993, Max Egenhofer
Introduction to Geographic Information Systems, Fall 1993, Kate Beard
Land Information Systems in Developing Countries, Fall 1993, Harlan Onsrud
Land Development Design, Spring 1993, Harlan Onsrud
Interactive Land Information Systems, Spring 1993, Max Egenhofer
GIS Applications, Spring 1993, Kate Beard
Graduate Seminar, Spring 1993, William Mackaness
Capstone: Geographic Database Design for Bangor Hydro Electric Co., Spring 1993, Kate Beard
GIS Case Study, Spring 1993, Harlan Onsrud
Municipal GIS, Spring 1993, Kate Beard
Documentation of User Interface, Spring 1993, Kate Beard
GIS Applications II, Spring 1993, Kate Beard

Data Quality, Spring 1993, Kate Beard
GIS Theory, Spring 1993, Harlan Onsrud
Graduate Project, Spring 1993, Max Egenhofer
Visualization of Data Quality, Spring 1993, Kate Beard

3. Buffalo

Geographic Perspectives and World Issues, Fall 1993, Hugh Calkins
Geographic Information Systems, Fall 1993, Paul Densham
Geographic Information Systems, Fall 1993, David Mark
Spatial Decision Support Systems, Fall 1993, Paul Densham
GIS Design, Fall 1993, Hugh Calkins
Univariate Statistics in Geography, Fall 1993, Sam Cole
Regional Analysis, Fall 1993, Peter Rogerson
Advanced Topics in GIS, Fall 1993, David Mark
Land-Use Transportation Models, Fall 1993, Michael Batty
Advanced Research Seminar, Fall 1993, Peter Rogerson
World Civilization, Spring 1993, Michael Batty
Geography of Economic Systems, Spring 1993, Paul Densham
Maps and Mapping, Spring 1993, David Mark
Multivariate Statistics in Geography, Spring 1993, Stewart Fotheringham
Locational Analysis, Spring 1993, Paul Densham
GIS Applications, Spring 1993, Hugh Calkins
Thematic Cartography, Spring 1993, Barbara Buttenfield
GIS Algorithms and Data Structure, Spring 1993, David Mark
Introduction to Grad. Cartography, Spring 1993, Barbara Buttenfield
Census Data & Their Use, Spring 1993, Hugh Calkins
Spatial Statistics, Spring 1993, Stewart Fotheringham
Advanced Topics in Cartography, Spring 1993, Barbara Buttenfield
Graduate Internship, Spring 1993, Stewart Fotheringham
Advanced Research Seminar, Spring 1993, Stewart Fotheringham

APPENDIX 5 - GRADUATE DEGREES GRANTED AT NCGIA SITES

1. Santa Barbara

Mollett, Michael, MA, Winter 1993, Degree by examination. (Couclelis, Goodchild, Larry Ford (SDSU)).

Fricke, Lisa, MA, Spring 1993, Degree by examination. (Michaelsen, Loaiciga, Davis).

Hess, Lisa, MA, Spring 1993, L-Band Radar Detection of Standing Water in Forested Wetlands of Coastal Georgia. (Simonett, Melack, Davis).

Day, John, MA, Spring 1993, Imaging Coniferous Forest Gaps with synthetic Aperture Radar. (Davis, Melack, Michaelsen, Jack Paris).

Robinson, Timothy, MA, Spring 1993, Fate and Transport of Agricultural Contaminants from Rice Paddies; Impact Sampling Strategies and the Potential Envirnomental Degradation to Dry Tropical Costal Wetlands - Guanacaste, Costa Rica. (Loaiciga, Church, Jones).

Burke, Lauretta, MA, Spring 1993, Environmental Equity in Los Angeles. (Goodchild, Michaelsen, Anselin).

Cogan, Christopher, MA, Summer 1993, Quantitive Analysis of Habitat Use by the California Condor. (Davis, Goodchild, Estes).

Dodson, Rustin, MA, Summer 1993, Integrating GIS and Spatial Analysis: An Implementation and Appraisal of Two Prototype Software Linkages. (Goodchild, Anselin, Tobler).

Beardsley, Karen, MA, Fall 1993, Compiling a Digital Map of Managed Areas at the National and State Levels. (Estes, Davis, Goodchild, Star).

Fairbanks, Dean, MA, Fall 1993, Relationship of GIS-based Environmental and Remotely Sensed Data to Floristic Gradients within California Vegetation Communities. (Estes, Davis, Haller, McGwire).

Springer, David, MA, Fall 1993, Determining the Air Permeability of Porous Materials as a Function of a Variable Water Content under Controlled Laboratory Conditions. (Loaiciga, Keller, Everett).

Rosenthal, C. Walter, MA, Fall 1993, Mapping Montane Snow Cover at Subpixel Resolution from the Landstat Thematic Mapper. (Dozier, Michaelsen, Mertes).

Friedl, Mark, PhD, Fall 1993, Correspondence Between Remotely Sensed Data and Land Surface Energy Balance Over a Tallgrass Prairie. (Davis, Dozier, Gautier, Michaelsen, John Price).

Nolin, Anne, PhD, Fall 1993, Radiative Heating in Alpine Snow. (Dozier, Mertes, Michaelsen, R. Davis, D. Matson).

2. Maine

Al Taha, Khaled, PhD, Surveying Engineering, December 1992, Temporal Reasoning in Cadastral Systems.

Miri, Bouchra, ME, Surveying Engineering, August 1993, Data Quality: Transformations Across Scales.

Pollock, D., ME, Surveying Engineering, May 1993, User interface considerations in vehicle navigation systems design.

Richards, J., MSc, Surveying Engineering, May 1993, Exploratory access to geographic data based on the map-overlay metaphor.

Sharma, Jayant, MSc, Computer Science, August 1993, Topological Relations Between Regions in Raster Space.

3. Buffalo

Basu, Pushpal, MA, February 1993, Linking Road Inventory Management System (RIMS) to Scarborough's Single Line Street Network (SLSN): Discussion of a GIS Prototype.

Chen, Shou-wen, MA, February 1993, Two-Dimensional Run-Length Encoding from Vector Representations and Polygon Overlay Based on Two-Dimensional Run-Length Encoding.

Crane, Todd, MA, June 1993, A Graphical User Interface for Map Production Within the Environmental Restoration Program at Los Alamos National Laboratory.

Cui, Xiabo, MA, June 1993, Design and Implementation of a Spatial Query and Information Display System for Real Property Management in Local Government.

Fly, Paul, MA, February 1993, Hypermedia and Ethics in Cartography.

Leitner, Michael, MA, June 1993, Prototype Rules for Automated Map Generalization.

Phelan, James J., MA, February 1993, Assessment of the 1990 TIGER/Line Files of the New York Metropolitan Region.

Schwartz, Paul, MA, September 1993, Teaching Cartograhic Type Design in a Digital Environment.

Ding, Yeumin, PhD, June 1993, Strategies for Parallel Spatial Modeling on MIMD Computers. (Densham).

Wu, Victor, PhD, August 1993, Querying Spatial metadata Based on Spatial Objects. (Buttenfield).

Gould, Michael D., PhD, Feburary 1994, PhD, Human Computer Interaction for Geographic Information Systems: Spatial Language in English and Spanish". (Mark).

Weber, Christopher, PhD, February 1994, PhD, Sonic Enhancement of Map Information: Experiments Using Harmonic Intervals.