NATIONAL CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS

ANNUAL REPORT

Year 8
(January 1, 1996 - December 31, 1996)

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

30 June 1997

NATIONAL CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS

ANNUAL REPORT

Year 8
(January 1, 1996 - December 31, 1996)

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 cooperative agreement was extended in 1994 for an additional three years, to December 31, 1996. 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 eighth full year of operation. Two major new research initiatives were begun, on GIS and Society: The Social Implications of How People, Space, and Environment are Represented in GIS (I19), and Formal Models of the Common-Sense Geographic World (I20). I19 is the first NCGIA research initiative to be planned mostly outside the center's three institutions. Education programs continued to be directed to K-12, GIS in the community colleges, and the development of new curriculum materials in GIS and remote sensing. Two additional collaborative projects were initiated under the Collaborative Grants program, and the Visiting Scholars program continued to support the work of visiting researchers at NCGIA sites. The program of collaboration with the European Science Foundation's GISDATA program continued, and the second joint Summer Institute for Young Scholars was held in Maine.

The University Consortium for Geographic Information Science held its first Annual Assembly. All three members of the NCGIA consortium were among the roughly 30 founding institutions to join the consortium in 1995.

1. BACKGROUND

1.1 NCGIA's 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. In 1994 the cooperative agreement was extended for a further three years, to December 31, 1996, and augmented with a $100,000 per year Visiting Scholars Program. The eighth year's operation began officially on January 1, 1996. 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, and a second peer review was conducted in 1992 as part of the process of renewal of the cooperative agreement.

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 12/31/96. 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, and are available through the Center's main web site (http://www.ncgia.ucsb.edu).

1.2 The New NCGIA 1997-2000

NCGIA was created as a three-institution consortium in response to NSF's 1987 solicitation. As originally conceived, the center was to have undertaken its mission for eight years, and the fate of the center at the end of this period was undefined.

Many fundamental changes occurred in the eight years from 1988 through 1996. The use of geographic information systems and geographic information analysis spread across virtually all of the disciplines that deal with the surface of the Earth, and GIS was adopted widely in many sectors of the economy. By 1994 the Office of Management and Budget was able to report some $4.4 billion of activity within federal agencies alone concerned with geographic information, and estimates of the total annual value of this sector in the national economy ranged upwards of $10 billion. Many other indicators were similarly bullish about the success of GIS and other geographic information technologies.

Despite (and perhaps because of) this success, however, GIS remained a subject of intense research, and there was increasing agreement that success in the future depended on the existence of a healthy basic science community, in an area that was increasingly being called *geographic information science*. Discussions within the center, with the Board of Directors, and with many other parties led strongly to the conclusion that any proposal for future funding of the consortium from NSF should emphasize basic science. Accordingly, in November, 1995, a new proposal to NSF entitled "Advancing Geographic Information Science" was submitted to NSF on behalf of NCGIA, requesting funding for three years beginning in January 1997. Following a lengthy review process, including site visits, and an addendum to the proposal submitted in August 1996, a new cooperative agreement was signed between UCSB and NSF effective February 15, 1997. At the same time, fundamental changes were introduced into the nature of NCGIA. Instead of an organization created to respond to an NSF solicitation, the new NCGIA will be a free-standing consortium of the three institutions, with an outstanding track record of collaborative research. Each of the three sites will have a Director (UC Santa Barbara: Keith Clarke; SUNY Buffalo: David Mark; University of Maine: Max Egenhofer). There will be an Assistant Director (Karen Kemp), and the Executive Committee of the three Directors and the Assistant Director will be chaired by Michael Goodchild. A memorandum of understanding was signed by the three institutions in early 1997 to formalize these changes.

The new NSF-funded project, now named in honor of Bernard Varenius, a 17th Century Dutch geographer and author of *Geographia Generalis*, will be administered as a project of UC Santa Barbara, with subagreements with the University of Maine, SUNY Buffalo, and the University of Minnesota. Annual reports of the Varenius project will be submitted to NSF, and the NCGIA annual report will be restructured in 1997 to reflect these changes. Thus this will be the last Annual Report issued in this format. Initiatives still active on 12/31/96 will be brought under the new structure being implemented to manage the Varenius project.

Further details of the Varenius project, including the complete proposal and other documents, can be accessed at the NCGIA web site www.ncgia.ucsb.edu.

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 the establishment of a Steering Committee including the initiative leaders, and others prominent in the field from outside the three Center institutions. The committee plans a specialist meeting, to be attended by professionals from outside the Center, selected by invitation following an open call, 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 Year 8 two new initiatives were begun, and one was completed, leaving a total of six active initiatives at the end of year 8. The following sections describe progress on each of the initiatives active or planned in 1996.

Initiative 8: Formalizing Cartographic Knowledge (began October, 1993). The I8 Specialist Meeting was held in Buffalo in October 1993. The goal of the initiative is to research needs in automated map compilation, generalization and production. In specific problem domains, knowledge representation and formalization will improve the efficiency, accuracy, and consistency of cartographic data or cartometric analysis.

Four research objectives drive initiative research:

1. Formalizing a Cartographic Language: definitions of terms/elements, labels for transformations, and knowledge representations for design and for manipulation.

2. Formalizing Evaluation: measures of efficiency; modeling communication.

3. Knowledge Acquisition/Elicitation: modeling users' knowledge, acquiring knowledge from redesigned user interfaces, testing methods to elicit knowledge (such as hypermedia, amplified intelligence, reverse engineering and inventory of maps and specifications.

4. Structuring / Modeling Knowledge: embedding knowledge in data models, exploring promising representations for knowledge, applying complex operators to novel data structures, and developing mechanisms to guide use of knowledge and metaknowledge.

Research this year has focused in three areas: first, the representation of uncertainty by graphical displays; second, the formalization of spatial metaphors to navigate through very large archives of (possibly nonspatial) data; and third, the formalization of coordinate and computational strategies for manipulating large cartographic datasets. Work has continued at Colorado, Maine, Buffalo, and Switzerland by researchers who attended the original I8 Specialist Meeting (1993) in Buffalo. Some of this work is related to the Alexandria Digital Library Project continuing at Colorado and UCSB.

At Buffalo, doctoral student Brandon Plewe has developed a taxonomy of gradation, or inherent imprecision of information that is difficult to represent in a spatial database faithfully but which often underpins

spatial decision-making in GIS. The taxonomy identifies discrete, stepped, multi-modal and continuous gradation. Several empirical case studies demonstrate how predicates may be formalized for these types of gradation to integrate remotely sensed, cartographic and field-collected spatial data into GIS models. Brandon defended his dissertation 24 March 1997. He accepted a tenure-track faculty position at Brigham Young University.

Barbara Buttenfield and Robert Weibel have developed a taxonomy applying Bertin's visual variables to a cross-tabulation of uncertainty measures and GIS data types. In the USA, the Federal Information Processing Standard FIPS-173 and the subsequent Content Standard for Digital Geospatial Metadata include specifications for data quality reports, including components of lineage, positional accuracy, attribute accuracy, completeness, currentness and logical consistency. The metadata standard states that when spatial variation in quality occurs, thematic overlays may be constructed as diagrams or thematic map depictions. No guidelines are provided for symbolization, level of generalization, or other graphic design criteria for these quality reports. A paper reporting this has been recently submitted.

Research by Michael Leitner (a Buffalo doctoral student supervised by Barbara Buttenfield) focuses on effective graphical tools for displaying uncertainty. Following subject testing experiments, we have discovered rules for graphical displays of attribute uncertainty. Specifically, if an application requires that the correct decision be reached in the shortest possible time, attribute uncertainty should be represented by varying symbol lightness (more certain attributes should appear lighter on the CRT display). If value is unavailable, symbol saturation or texture can be applied, although subject response times will be slower. Michael defended his dissertation in October, 1996, and a number of publications have appeared. Michael accepted a faculty position at Louisiana State University.

Many of the well-known impediments to automating map generalization derive at least in part from the computational limitations of conventional coordinates when changing map scale and filtering cartographic details. Geoff Dutton's hierarchical notation (QTM) for location encodes addresses as 64-bit fields capable of describing coordinates, attributes, and metadata. In recent months, he has extended his notation to automatically identify neighbors and compute adjacency measures. He will present his research at AUTO-CARTO 13 in Seattle (April, 1997) and at the International Cartographic Association meetings in Sweden in June 1997. Geoff intends to complete his degree in the coming year.

Geographical analysis and modeling is complicated by an increasing volume of information input and output. For another researcher to replicate a GIS model, one must exchange not only the data and models but the parameters and tolerance thresholds, in a chronological report of the GIS processing steps. At Colorado, Ming Tsou and Barbara Buttenfield developed a system to directly manipulate geographical data by using object-oriented approaches and graphic user interface (GUI) design. For Master's work, Ming conducted a case study for a residential siting problem, and presented this work last summer in Europe. Extensions to the original effort will be presented in 1997 in Sweden. Direct manipulation lets the user define icons to represent the geographical data and manipulate the icons to create the chronological report of GIS processing. Object-oriented approaches are adopted as a first step towards developing an operational procedure for distributing the parameters and models of a GIS application wholly encapsulated in object structures for another user to replicate a GIS model. This study suggests that the next generation of GIS user interfaces could provide an intelligent agent to assist users to search, query, and operate on data.

In a search through a digital data archive, a user may define an initial query that returns hundreds of 'hits'. Systems present search results either in a list, or by alerting the user that the result set is too large. If one could organize a large result set in such a way that a user could view it all at once, then query refinement might proceed by direct manipulation of a symbolic representation of the set. We have developed a graphical display not unlike a scatter plot, where retrieved items are represented by points. Point locations are derived from statistical clustering of keyword similarities to put similar items closer together. The displays are hierarchical. One can zoom in to the scatter plots to uncover additional items. At present, we have implemented an operable solution for small data sets (under 100 result set items). Our solution appears to be scalable and Andre is currently demonstrating its applicability to larger (1,000 item) response sets for his dissertation. Andre expects

to defend his dissertation in August 1997. At Colorado, first year doctoral student Sara Fabrikant has begun designing subject testing experiments to test user response to these displays for free- and structured-browsing tasks. We hope to implement spatial metaphors for Web queries.

At Maine, Kate Beard spent a sabbatical month at UCSB, working on a schema to represent graphically the spatial extent, temporal identifiers and thematic attributes of data sets when a large number of responses to a query are encountered. Kate uses the cartographic principle of "small multiples" to generate iconic glyphs. Each glyph is a bar chart (effectively) identifying the data footprint and timestamp/update cycle. Additional thematic information identifies the degree to which a given data set responds to the query criteria (e.g., resolution, data themes, data format, producing agency). The glyph design allows darker icons to represent datasets that are more 'fit for use' in the context of a given query. Kate is currently preparing papers reporting her work.

In a physical map library, it is a challenge to predict and monitor points in growth at which operational procedures should be "ramped up" to maintain effective access to holdings. Often measures of size are based on the number of items currently archived. In a digital library, the number of items is difficult to count, since an item can be a map, an item contained in a map image, or a procedure operating on maps or map items. Complicating this is the spatial metadata, particularly lineage records, which tend to grow with every map processing operation. Barbara Buttenfield published a paper applying allometric models to library management of very large archives. Additions to the catalog of the Alexandria Digital Library are currently monitored on a monthly basis (Buttenfield at Colorado and Randy Kemp at UCSB) with expectation of additional papers in the coming year.

A conference event planned for the coming year is the Second Workshop on Progress in Automated Map Generalization, to be held 19-21 June 1997 in Gaevle, Sweden. As happened in the first workshop in Barcelona, a small number of junior and senior researchers from around the world will present results of research on generalization theory. The goal of this meeting is to report demonstrated progress, concentrating on empirical results. This will be the fifth in a series of international meetings on generalization research held during the life of Research Initiative 8. A second goal was to introduce junior researchers from Europe and North America and foster an international collaborative environment for continuing research. The Steering Committee includes Robert Weibel, leader; Jean-Phillipe Lagrange, IGN-Paris; and Diane Richardson, Canada Centre for Remote Sensing.

Doctoral research will continue in Switzerland: Geoff Dutton, working with Professors Kurt Brassel and Robert Weibel in Zurich, should complete his dissertation in the coming year. In Buffalo, Andre Skupin's work should be ready for defense this coming summer. At Colorado, work applying formal spatial metaphors to navigation and orientation within very large data archives will continue.

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.

Initiative 10 began its closing activities during 1996. A small workshop was organized by Reg Golledge and Max Egenhofer in Santa Barbara June 7-8 on the topic "The Relationship Between GIS and

Disaggregate Individual and Behavioral Transportation Modeling", with the aim of exploring this major application area for space-time data models and spatio-temporal reasoning. This activity completed the cycle of planned effort in I10, which started with a strong temporal presence, then shifted to a predominantly spatial context, and now finishes with suggestions for expanding GIS into the transportation modeling area by emphasizing both temporal and spatial features. The temporal features are embedded in the concept of episodic activities and activity scheduling on the part of households and individual household members, with data being collected using temporal procedures such as travel diaries, episodic surveys, and long-term data collection from panels. The activity scheduling and activity-based approach as epitomized within the context of this symposium appears to be a very challenging set of circumstances for potential integration of both spatially dominant and temporally dominant GIS.

The symposium brought together academic participants from fields such as economics, civil and environmental engineering, transportation engineering, architecture and urban planning, and geography, and representatives from federal and state government including the Department of Transportation, CalTrans, and Oakridge National Labs. Ten presentations were made during the two days of the workshop, which was attended by 21 participants, including Mike McNally (UC Irvine); Stephen Greaves, Louisiana State University; Mei-Po Kwan, Ohio State University; Frank Southworth, Oak Ridge National Laboratory; Harvey Miller, University of Utah; Andrew Harvey, St Mary's University; Ken Vaughn, Duke University; and Don Janelle, University of Western Ontario. Selected papers will appear in a special issue of the journal *Geographical Systems* in 1998.

Final revisions were made to the book *Spatial and Temporal Reasoning in GIS* (Editors: Egenhofer and Golledge). The book includes papers developed from presentations at the I10 Specialist Meeting, and will be published by Oxford University Press late in 1997.

Ph.D. students Jayant Sharma and Rashid Shariff completed their doctoral disserations at Maine in 1996. Sharma's Ph.D. thesis focused on integrated reasoning over topological relations and cardinal directions. Shariff's thesis formalized and calibrated a model for natural-language spatial relations. Dimitris Papadias and Max Egenhofer developed formalisms and algorithms for hierarchical spatial reasoning. Finally, Egenhofer with Nectaria Tryfona, Doug Flewelling, and Joao Paiva continued their investigations of consistencies of multi-resolution databases.

Significant intellectual progress was made in several areas of spatio-temporal reasoning. For the semantics of natural-language spatial relations, which often form the desired answers from a geographic information system (GIS), we developed and tested a formal model that captures metric details for the description of natural-language spatial relations. The metric details are expressed as refinements of the categories identified by the 9-intersection, a model for topological spatial relations, and provide a more precise measure than does topology alone as to whether a geometric configuration matches with a spatial term or not. Similarly, these measures help in identifying the spatial term that describes a particular configuration. Two groups of metric details were derived: splitting ratios as the normalized values of lengths and areas of intersections; and closeness measures as the normalized distances between disjoint object parts. The resulting model of topological and metric properties was calibrated for sixty-four spatial terms in English, providing values for the best fit as well as value ranges for the significant parameters of each term. To bridge the gap between computational models for spatial relations and people's use of spatial terms in their natural languages, we calibrated the model for the geometry of spatial relations for a set of 59 English-language spatial predicates. The calibration identifies ten groups of spatial terms with similar properties and provides a mapping from spatial terms onto significant geometric parameters and their values. The model provides a basis for high-level spatial query languages that exploit natural-language terms and serves as a model for processing such queries.

As geographic information systems (GISs) have gained wider acceptance and application, interest in spatial modeling and reasoning has deepened. Our work in spatial-relation modeling focused on computational methods that exploit qualitative spatial information for reasoning about objects in a geographic database. Unlike previous approaches, we rely on relations that apply to extended spatial objects. The objective is to enhance geographic information systems with mechanisms to deal with complex spatial concepts for data

selection and integration, particularly to define a framework within which reasoning across different formalisms for spatial relations can be combined such that more precise spatial information is obtained. The result of this work is that the combination of topological and directional relation information enhances the reasoning power of a qualitative spatial reasoning system. The findings of this work are significant, because the formal approach clearly identifies the different types of qualitative spatial reasoning that can be performed; they show how and when simpler spatial inference mechanisms can be combined to give results equivalent to those obtained with a more complex spatial inference mechanism; and through the systematic derivation of composition tables for qualitative spatial reasoning about topological and directional spatial relations, they lead to new insights about properties for models of directional relations among extended spatial objects.

In several applications, there is the need to reason about spatial relations using multiple local frames of reference that are organized hierarchically. Our worked focused on hierarchical reasoning about direction relations, a special class of spatial relations that describe order in space (e.g., north or northeast). We assumed a spatial database of points and regions. Points belong to regions, which may recursively be parts of larger regions. The direction relations between points in the same region are explicitly represented (and not calculated from coordinates). Inference mechanisms are applied to extract the direction relation between points located in different regions and to detect inconsistencies. We studied two complementary types of inference. The first one derives the direction relations between points from the relations of their ancestor regions. The second type derives the relation through chains of common points using path consistency. We designed and prototyped algorithms for both types of inference and compared their computational complexity. We found that inference through points is in the worst-case scenario significantly more expensive than inference through regions.

Initiative 15: Multiple Roles for GIS in US Global Change Research (began March 1995). The general context for this initiative is provided by the apparently widely held perception that GIS and related technologies will play an important role in global change research. Remote sensing will clearly be the most important source of data for global change research, at least within its physical dimensions, because of its potential for uniform, high resolution coverage of the surface of the Earth. GPS is clearly important to all kinds of field observation. The importance of GIS, on the other hand, can only increase as global change research becomes more computationally and data intensive, as it moves from studies of single processes to integrated modeling, and as it struggles to link human and physical processes.

I15 held two specialist meetings, the first to develop consensus among the global change research community about needs and requirements; and the second to develop an appropriate response from the GIS community. The first meeting was held in Santa Barbara in March, 1995, and its findings were published as *Technical Report 95-10*.

The second specialist meeting was held in Santa Fe, NM, January 25-26, immediately following the NCGIA-sponsored Third International Conference/Workshop on Integrating GIS and Environmental Modeling. The original intent had been for the first specialist meeting to bring together global change researchers to give their perspective on the objectives of the meeting; and for the second specialist meeting to bring GIS researchers together to discuss possible solutions. That model was modified when it became clear that the first specialist meeting would not be able to divorce its discussions from GIS quite so cleanly; and when the range of problems and issues identified in the first meeting was found to be so broad. Instead, the second specialist meeting was planned as a much smaller gathering (20 rather than 50) with a discussion focused on data modeling as an organizing framework.

The report of the second specialist meeting was published as *Technical Report 96-5*. It identified major problems in bringing the data models used in the various global change disciplines into any kind of common framework, and cited examples in support. One of the most significant problems concerns data quality. Not only are descriptions of data quality commonly lacking in shared data sets, but the terminology needed to create them is not even shared across disciplinary boundaries. The meeting found major problems in

reaching a common understanding of the term 'data model'—the GIS community tends to take a much more generalized view of the term and associated process than the oceanography community, for example.

We have determined that the term 'data model' must be interpreted in a variety of ways depending on the domain of the usage. In oceanography, for example, data model options are enumerated only within the narrow domain of data familiar to oceanographers; GIS researchers are likely to have the broadest domain of interpretation. We have also determined that data modeling can be extended as a useful framework for all aspects of the data life cycle, both analog and digital, and that data modeling decisions and transformations occur at many stages, both in and outside the digital domain. We have identified five fundamental extensions of GIS data models—to three spatial dimensions, time, the curved surface of the Earth, multiple scales, and uncertainty. While significant progress has been made on the first two, there is very little to date on the next two, and virtually none on the last.

At Santa Barbara, the Spherekit project to develop a general software package for spatial interpolation on the curved surface of the Earth made major progress. The code includes functions for 'smart' interpolation of fields that take into account topography and other deterministic variables; several different interpolation methods; and numerous visualization options. The project is the work of Rob Raskin, Chris Funk, and Cort Willmott, a visitor to NCGIA from the University of Delaware. Further details are available at http://www.ncgia.ucsb.edu/pubs/spherekit/main.html.

John Felkner completed his Masters project at Santa Barbara on international scientific data sharing policy, using the recent WMO controversy as a case study. The work was presented at the 1996 AAG meetings in Charlotte, NC, and was extended to include several other data collections as further case studies. Joseph Scepan is working on his dissertation project which involves a preliminary assessment of the accuracy of the IGBP "Fast Track" 1 km land cover project. This work is an extension of John Estes' involvement on the IGBP Land Cover Working Group and the Validation Working Group. Estes and Scepan attended a meeting on this effort at the European Union Joint Research Center in Ispra, Italy, in May, where a schedule of work assignments was established for Santa Barbara, JRC, and the USGS EROS Data Center.

Dale Quattrochi (NASA) and Michael Goodchild edited a volume of 16 solicited chapters titled *Scale in Remote Sensing and GIS* (CRC Press, 1997). The book includes case studies ranging from local to global, chapters on major theoretical frameworks for scaling and multiscale analysis, and practical solutions adopted in modeling human and physical processes.

John Estes has been involved in two major efforts aimed at providing the core data required for global change research. These are the Japanese-led Global Map Project and the US-led Earthmap Project. Estes is chair of the International Steering Committee of the former and a member of the Executive Committee of the latter. Both are directed at providing up-to-date small scale (1:1,000,000) coverage of the globe for research and management use. The Geographical Survey Institute of the Ministry of Construction in Japan is the site of the Global Map Secretariat, while negotiations are under way for a place for Earthmap at the National Academy of Sciences. In November, UC Santa Barbara hosted a meeting of the Global Map Project attended by approximately 50 international participants.

Keith Clarke joined the UCSB faculty in September 1996 from Hunter College of the City University of New York. Much of his recent work centers on simulations of urban growth, including case studies of the California Bay Area. Tim Foresman (University of Maryland, Baltimore County) demonstrated his related Baltimore/Washington Corridor Land Cover Change Project results at the Baltimore national meetings of the American Society of Photogrammetry and Remote Sensing. The model simulates urban change on the East Coast from 1790 to the present.

At Maine, Bheshem Ramlal is completing his dissertation work on a mixed vegetation model for soil information. His model treats soil properties as exhibiting both continuous and abrupt change. The model incorporates measurements of soil properties, quality of the measurements, delineations of abrupt changes in properties, and an interpolation method to generate fields form the above components. His interpolation

method accommodates both discontinuities in a soil property and the reliability of the measured position and attribute. He presented preliminary findings in a paper at the environmental modeling conference in Santa Fe in January.

Kate Beard presented a paper on organizing metadata at the environmental modeling conference in Santa Fe. The paper investigates metadata content and collection strategies for marine data and for marine-related process models such as circulation models. Interest in methods for data description is now widespread in the geographic information community. The report of a one-day metadata workshop organized in Santa Barbara in November 1995 is available at http://alexandria.sdc.ucsb.edu/metadata. Kate Beard and Terry Smith co-authored a paper; "A Framework for Meta-Information in Digital Libraries", for a book edited by Amit Sheth and Wolfgang Klaus to appear this year from McGraw Hill. Kate Beard and a graduate student Vyjayanti Sharma have been working on evaluation and visualization of metadata for scientific datasets. A paper on this work, "Mulitidimensional Ranking in Digital Spatial Libraries", will appear in the *International Journal of Digital Libraries*.

Buffalo researcher Chris Larsen, assisted by graduate student Kelly Pew, has been investigating the spatial pattern of wildfires, with the aim of increasing the potential ability to predict the occurrence of large fire years in different areas. Larsen is currently focusing on a case study of fires in western Canada.

The Second International Symposium on Spatial Accuracy Assessment in Natural Resources and Environmental Sciences took place in Fort Collins, CO, May 21-23. Over 100 papers were presented, including a keynote from Michael Goodchild and a paper on NCGIA accuracy research by Gary Hunter. The conference series is a more-or-less direct descendant of earlier NCGIA initiatives, including I1 and I7. A session on modeling gradual and abrupt spatial transitions contained several papers of direct relevance to I15's objectives, and it appears that substantial progress is being made on this issue. Other papers reflected growing interest in conditional simulation as a way of modeling uncertainty in spatial data.

There has been discussion of possible linkages between I15 and I19, the initiative on GIS and society. At Santa Barbara, James Proctor has been exploring a possible research project within I19 that would examine the nature of GIS practice in global change research, and has had discussions with Bill Turner (Clark University) about possible collaborations with the LUCC (Land Use/Cover Change) project.

Auto Carto 13 will serve as the closing conference event for I15. Eight papers were submitted and six will be presented. Papers include: K. Beard, "Managing Metadata for Global Scale Coverages"; B. Ramlal and K. Beard, "A Method for Handling Data that Exhibit Mixed Spatial Variation"; W. Tobler, "Demography in Global Change Studies"; R. Raskin, C. Funk, and C. Wilmott, "Interpolation over Large Distances Using Spherekit"; D. Mageean, "Using Population and Environmental Data to Address the Problem of Human Dimensions of Environmental Change"; and R. O'Connor, M. Jones, D. White and C. Hunsaker, "Scale and the Extent of Natural Ecoregions in the United States".

Initiative 16: Law, Public Policy and Spatial Databases (begun 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.

The major activities in the past year have been steady progress on research and the successful defense of the Ph.D. dissertation of Xavier Lopez.

A proposal to fund an international closure meeting for the initiative has been drafted and is titled "Geographic Information Policies for a Global Information Infrastructure". The proposal to fund this Advanced Study Institute (ASI) will be submitted to NATO and other organizations.

The web page for the initiative continues to be maintained at http://www.spatial.maine.edu/I-16/I-16_home.html. In addition to the specialist meeting proceedings, this site provides access to papers prepared by I-16 researchers, a legal and information policy bibliography, and links to related legal index sites.

Xavier Lopez completed his case study and survey work and defended his PhD dissertation on "The Impact of Law and Information Policy on the Dissemination and Commercialization of Scientific and Technical Databases: A North American - European Community Comparative Study". His research addressed international issues in the interplay of access, copyright, and cost recovery issues relative to geographic databases. The work focused on the policies of national mapping agencies in Canada, France, Great Britain, and the United States and the effects of those policies on key stakeholder groups. Lopez accepted a post-doctoral position at UC Berkeley's School of Information.

Although substantial anecdotal evidence has existed on the effects of governments following various information policy arrangements, the work by Lopez is one of the few systematic and comprehensive comparative investigations of government information policies. Responses were gathered from key groups of users of national mapping agency data sets (commercial intermediary users and academic users) as well as from informed personnel within national mapping agencies. A few sample observations are as follows:

1. According to respondents, nationally mandated policies are the primary determinant driving the cost-recovery practices being undertaken by those mapping agencies following such policies.

2. Responses indicated that academic end users and commercial intermediary users (i.e., the commercial sector attempting to add value and resell) in Canada, France, and the UK share some very similar experiences in terms of access to and commercialization of spatial data from their national mapping organizations.

3. The study found strong evidence that the imposition of intellectual property rights by government on public information was a key variable in determining access to and commercialization of national mapping agency data sets.

Paul Schroeder continued work on his PhD program. His research is focusing on effective end-user access to electronic data sources and his approach serves as a counter-approach to studies of network deployment and the development of centralized information services. The role of GIS is pivotal in this work, both as a tool to evaluate the distribution of information services and as an example of the advanced information systems to which the general public will increasingly expect access. His dissertation work on end-user access models will utilize the ongoing experiences in increasing access to GIS technology, datasets and other information resources in Maine's libraries and schools.

Robert Reis is working on issues derived from Initiative 16, namely the derivative impact potential of GIS/GIA on public and private rights in an information-based legal system. Reis is beginning a case study which will focus on developing the relationship of geographic information systems and analysis to information-dependent social and legal rights using the Public Trust Doctrine as a case study. The purpose of the study is not only to determine the impact of geographic information systems on the Public Trust Doctrine, but to determine the converse impact of the Public Trust Doctrine on the development of geographic information systems by isolating issues and values which have the potential to shape the development of GIS.

Initiative 17: Collaborative Spatial Decision Making (begun September 1995). I17 received approval in principle following the June 1993 Board meeting and approval in detail at the June 1994 meeting. The objectives of this 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.

The Specialist Meeting was held in Santa Barbara September 16-19, 1995. The organizers sought to bring together a wide range of researchers from academia as well as from the public and private sectors. In particular, the organizers encouraged the participation of researchers with interests in linkages between GIS and group-based decision-making, researchers with international links, and researchers who could provide specific examples of the strengths and weaknesses of GIS in CSDM research.

A special session on collaboration was held at the Third International Conference/Workshop on Integrating GIS and Environmental Modeling, held in Santa Fe New Mexico, January 21-25, 1996. I-17 specialist meeting participants were invited to submit papers for this session. The session was chaired by Steve Carver, University of Leeds. I-17 related papers were: Steve Carver, University of Leeds; Steve Frysinger, James Madison University; and Rene Reitsma, CADSWES, University of Colorado; "Environmental Modeling and Collaborative Spatial Decision-Making: Some Thoughts and Experiences Arising from the I-17 Meeting"; David A. Bennett, Southern Illinois University; Marc P. Armstrong, University of Iowa; and Greg A. Wade, Southern Illinois University; "Agent Mediated Consensus-Building for Environmental Problems: A Genetic Algorithm Approach".

The Specialist Meeting report was published as NCGIA Technical Report 95-14. A World Wide Web homepage has been created for the initiative [http://www.ncgia.ucsb.edu/research/i17/I-17_home.html]. This page contains a web version of the Specialist Meeting report. Also, I-17 meeting participants were asked to contribute active links for this page pointing at related research activities. Links are now provided to the following sites, all of which are sites maintained by I-17 meeting participants:

UW/UI Collaborative Spatial Decision Homepage, contains links to many other web sites. Timothy Nyerges, University of Washington and Piotr Jankowski, University of Idaho.

Centre for Advanced Spatial Analysis, Paul Densham and Mike Batty, University of London.

European GeoMed Project, Geographical Mediation System, link contributed by Thomas Gordon, German National Research Centre for Information Technology, Research Division on Artificial Intelligence.

In the summer of 1996, Paul Densham spent a week in Iowa and three weeks in Buffalo working in cooperation with Marc Armstrong and others in Initiative 17 research. Marc Armstrong spent one week of this period at SUNY Buffalo to continue his work with Densham. In addition there was a two-day meeting of five of the seven members of the I-17 Steering Committee (Co-leaders Densham, Armstrong and Kemp, Committee members Harris and Shiffer) in Buffalo in July. The Committee discussed progress on the initiative and plans for its closure.

While in Iowa, Densham and Armstrong talked to a number of researchers and graduate students about I17 and how they may become involved in initiative research. At Buffalo, similar discussions were held with a number of researchers, including Rajan Batta and NCGIA graduate students. The goals of these discussions were to raise awareness of the initiative and to involve these persons in initiative research.

Densham and Armstrong worked on a number of papers that contribute to Initiative 17. They revised a paper that had been accepted by *Environment and Planning B* which contributes to both I6 and I17; and also worked on a journal article on cartographic aspects of CSDM. This paper was restructured and additional material has subsequently been developed. Currently, it is nearly complete and there are plans to submit it to *Cartography and GIS*. Densham also worked on a paper on visual interactive modeling that is being written for submission to *Environment and Planning A*; this paper is still in progress.

Armstrong and Densham have been collaborating on a new approach to the decomposition and representation of multiple scenarios, formulated, for example, by several members of a decision-making body, so that they can be summarized and visualized. This approach is based on an extended form of map algebra. The decomposed solutions are transformed into matrix form, operated on using a set of operations to derive, for example, summary measures and indices of agreement, and the transformed information is then visualized so that it can be used by individuals working to sort through the alternatives they have generated, or by groups who are working to reach consensus. While at Buffalo, Densham and Armstrong prepared an abstract on this topic for Auto-Carto 13. The proposed paper was accepted, has since been completed, was submitted for inclusion in the *Proceedings*, and will be presented in the first session of the conference.

Researchers working on projects related to I17 participated in a special session at GIS/LIS '96 in Denver this past fall. Karen Kemp (UCSB) organized the session and served as session chair. Four papers were presented and also published in the Proceedings of GIS/LIS '96.

Marc Armstrong has been researching new ways of decomposing problems so that they can be processed efficiently in parallel using a collection of distributed workstations, such as those that might be used by decision-makers in a CSDM session. Performance improvements that result from parallel processing are required to ensure that meetings are issue- and criteria-driven, rather than computation-bound when complex models are used to support decision-making. One way to implement distributed parallel algorithms is to use software that coordinates the execution of high-level parallel constructs in conventional software and hardware environments. To date, several have been developed, including Linda, PVM and MPI. One publication on this topic has appeared in *Computers and Geosciences*.

David Bennett (Southern Illinois University) and Marc Armstrong have been investigating ways that can be used to generate and evaluate new land management scenarios in multiple stakeholder settings. They have recently begun to focus on the use of a two dimensional genetic algorithm approach that is described more fully in two papers.

At University College London, Paul Densham is a co-Principal Investigator on a recently awarded grant "A Virtual Reality Centre for the Built Environment: Specialising in research applications and training for Construction, Retailing and Transport". This grant is sponsored by the Office of Science and Technology (Technology Foresight Programme), and is for the period October 1996 to September 1999 [Co-Principal Investigators: J.M. Batty, A. Penn (Project Directors), P.J. Densham, D.P. Chapman, B. Hillier, R. Mackett, M. Slater, G. Winch. OST Funding : £ 1,100,000; Industrial Match £ 2,200,000]. The center funded by this grant will research and disseminate ways of producing virtual built environments. This will enable those who locate, design, construct, deliver and manage facilities to explore ways in which the highest quality environments can be produced. Companies from the construction, retailing and transport sectors, along with computer and software vendors, are providing matching funds for the center. Densham's role in the center consists of three elements: to work on linking urban planning tools to GIS; to develop retailing applications that integrate GIS, spatial analysis and VR; and to contribute to the development and operation of a partnership program that disseminates VR methods and practices into industry. This grant will support some of the I17 research being undertaken by Michael Batty (University College London and Planning Group for I17) and Paul Densham (Co-leader of I17); more specifically, the grant will enable us to look at the integration of GIS, urban planning and virtual reality to support collaborative spatial decision-making.

Densham is also co-Investigator on a pending grant ["The International Movement of Expertise". Submitted to the Economic and Social Research Council (UK). Co-Principal Investigators: J. Salt (Project Director) and P.J. Densham. £ 93,088]. The overall aim of the proposed research is to investigate the impact upon global patterns of highly-skilled migration of evolving corporate strategies for the acquisition and movement of expertise, including the effects of developments in Information Technology. This research links to I17 because the investigators propose to analyze the interaction between new forms of electronic transmission of knowledge and expertise, particularly collaborative spatial decision-making tools, and the movement of personnel. An examination of how and why corporations are deploying CSDM tools will help to shed light upon desirable characteristics of such tools and the formulation of design criteria for the next generation of tools.

Other Initiative 17 research at Buffalo includes the efforts of researchers Rajan Batta and Peter Rogerson, and graduate students William Frank, Vedat Agkun and Geoff Adams. Adams assisted Pete Rogerson and Rajan Batta on a project (sponsored by CUBRC) to investigate the locations of automobile injury accidents in rural Erie county. The project's goal was to develop a benchmark against which the effectiveness of an experimental automated accident notification device could be measured. The work of Rogerson, Batta and Adams involved developing a probabilistic model of serious accidents, especially those occurring in locations in which there may be a significant time lag between the accident incident and the arrival of emergency services. The other research task was be the identification of geographical locations that are most likely to host life-threatening accidents with long time lags between occurrence and emergency service notification.

Frank and Agkun's efforts were focused on hazardous materials routing problems within the context of a GIS. Vedat Agkun was performing a study on the routing of a vehicle carrying hazardous material in the presence of a weather system. William Frank is also working on a study of route selection of hazardous materials; his work incorporates the element of the time of day the shipment is scheduled, as time of day has an effect on traffic volume, accident statistics, and possible curfew times. Both Frank and Agkun work under the supervision of Rajan Batta.

Other Initiative 17 activities include:

- Armstrong, working with Richard Marciano at the San Diego Supercomputer Center, has initiated work that uses a network of workstations (NOW) to implement parallel versions of algorithms used in GIS software. The underlying rationale is that the execution of computationally-complex analyses can consume large portions of time during a group meeting. If the computational burden can be spread amongst different workstations, a greater number of alternatives can be evaluated by the group during the course of a meeting. Initial results using a NOW environment at SDSC indicates that for a large spatial interpolation problem we are able to achieve results that are better than those obtained using the Cray T3D supercomputer at SDSC.

- Jon Gottsegen and David Lemberg, doctoral students at UCSB, have begun developing dissertation proposals directly related to discussions at the I17 specialist meeting. Lemberg's dissertation will address feasible alternatives generation and Gottsegen's will compare geographic concepts critical to the interests of stakeholders in environmental debates to the representations of spatial information from a geographic information system.

- Michael Figueroa (UCSB) completed his MA thesis on "Construction of an Exploratory Modeling System for Public Sector Location-Allocation Planning". Exploratory modeling takes a more flexible approach to modeling, allowing input from decision makers and others to be included in the modeling phase by potentially moving it from the analyst's office to the conference room table.

- Armstrong and Densham are completing a book chapter that summarizes alternative strategies for overcoming impediments to the solution of large geographical problems through the use of parallel processing.

- Yuemin Ding (NYNEX Science and Technology) and Densham have published a paper in the *International Journal of Geographical Information Systems* as the lead article in a special issue on parallel processing. This paper develops strategies that exploit the spatial structure of problems when decomposing them to run on parallel computers. The work reported in this paper is being used as a foundation for work on designing modelbase management systems (MBMS) that both support collaborative modeling efforts and run in parallel computing environments.

- Church and Figueroa have been working to develop a prototype for generating spatial alternatives in a spatial decision support system, the Regional Ecosystems and Land Management Decision Support System (RELMdss). The major objective is to develop and test: a method for generating alternatives within a location-allocation module; a graphical user interface to present alternatives; and, a method to spatially direct searches for alternatives.

Initiative 19: GIS and Society: The Social Implications of How People, Space, and Environment are Represented in GIS (began February 1996). The initiative focuses attention on the social contexts of GIS production and use and addresses a series of conceptual issues:

- In what ways have particular logic and visualization techniques, value systems, forms of reasoning, and ways of understanding the world been incorporated into existing GIS techniques, and in what ways have alternative forms of representation been filtered out?

- How has the proliferation and dissemination of databases associated with GIS, as well as differentiatial access to spatial databases, influenced the ability of different social groups to utilize information for their own empowerment?

- How can the knowledge, needs, desires, and hopes of marginalized social groups be adequately represented in GIS-based decision-making processes?

- What possibilities and limitations are associated with using GIS as a participatory tool for more democratic resolution of social and environmental conflicts?

- What ethical and regulatory issues are raised in the context of GIS and Society research and debate?

The initiative is led by Trevor Harris and Daniel Weiner, West Virginia University.

The Initiative 19 specialist meeting was held at the Koinonia Retreat Center, South Haven, Minnesota, March 2-5, 1996. The meeting was organized as a workshop. A call for position papers was emailed to numerous bulletin boards and posted in the AAG newsletter. In response, over 40 position papers and expressions of interest were received. After a peer review process, 32 position papers were accepted and invitations to attend were offered. Attendees were geographically distributed throughout the US and representatives from the united Kingdom and Switzerland were also present. All position papers were posted to an Initiative 19 Home Page on the World Wide Web: http://www.geo.wvu.edu/www/i19/page.

Based upon subsequent feedback and the post-meeting initiatives which it spawned, the specialist meeting should be considered a success. A plenary session provided the history of the initiative, identified the conceptual framework of the I19 proposal, and laid out the initial research themes. Subsequent plenary sessions addressed each of the conceptual issues in the proposal which were then followed by smaller break-out groups which later reported back to the whole group. Toward the end of the workshop, specific research topics were identified and break-out groups were formed to establish forums for discussion. Clusters of individuals interested in developing specific research projects were then established. Subsequent to the specialist meeting, four I19 research proposals were submitted to the NCGIA.

The specialist meeting successfully discussed and challenged our early conceptual ideas and research themes. This has acted to refine and focus them still further. The four research proposals all seek to provide vehicles suitable for pursuing the conceptual issues laid down in the proposal and elaborated at the specialist meeting (see list below). At the specialist meeting, there was also considerable discussion regarding the possibility of developing what became know as 'GIS2'. Although multiple meanings of GIS2 were presented and discussed, the core of this idea is an alternative GIS constructed with community participation and incorporating non-conventional knowledge types. One of the key objectives of GIS2 is to facilitate more inclusive spatial decision-making processes. Other key issues to emerge from the specialist meeting are discussed in the specialist meeting report (*Technical Report 96-7).*

The steering committee also organized two I19 sessions at the Association of American Geographers annual conference held in Charlotte, NC in April, 1996. The first session comprised a 'meet the editors' discussion in which Eric Sheppard and John Pickles provided an overview and responded to 'critics' and questions regarding the *GIS and Society* theme volume published by *CAGIS*, and the edited volume *Ground Truth*. The second session comprised several short presentations by members of the I19 steering committee which focused on the objectives, conceptual themes, and research projects of I19. Both sessions were well attended and generated substantial discussion and interest.

Much of the effort expended in the first six months of the year was focused on the specialist meeting and the AAG presentations. Out of these activities have come four research proposals which have been submitted to NCGIA and accepted for funding. These comprise:

- A regional and community GIS-based risk analysis, University of Minnesota
- GIS and Society research in the Kanawha Valley, West Virginia, West Virginia University and University of Kentucky
- The social history of GIS project, University of Kentucky and University of Hawaii at Manoa
- The ethics of spatio-visual representation: toward a new mode, University of California, Los Angeles, and University of Minnesota

The GIS History Project (Buffalo and Kentucky). The central goals of this work, also known as the CHGIS (Critical History of GIS) project. are to bring a variety of theoretical perspectives from contemporary social theory to bear on the question of GIS as social practice, to contextualize GIS in its social, political, and economic context (in contrast to more traditional internalist and hagiographic histories), to locate GIS in terms of a broader history of science and technology, and specifically to do so through an engagement with the systems and logics that were developed, the paths that were not taken (but could have been), and the institutional linkages that provided the context within which that which emerged came to be. The CHGIS Group began its work in spring 1996 directly following the I-l9 meeting at Koinonia in Minnesota, and submitted a proposal to the NCGIA for seed money. Funding to support the activities of the group was committed in late spring, and Eugene McCann was hired at the University of Kentucky as research assistant to the project for one semester and began work in late August.

The first efforts of the Group were devoted to extensive email discussion of the specific structure and content of the research that might be carried out through this project, and to building a strong group of research participants. The participants are: Jon Goss (Hawaii), David Mark (Buffalo), John Pickles (Kentucky) (Coordinators), and, Nick Chrisman (Washington), Michael Curry (UCLA), Oliver Froehling (Kentucky), Carol Hall (South Carolina), Ken Hillis (Wisconsin/Colorado), Patrick McHaffie (DePaul), Roger Miller (Minnesota), Eric Sheppard (Minnesota), Jon Taylor (Kentucky), and Dalia Varanka (BLM/Wisconsin-Milwaukee). A private listserver called CHGIS was established at Kentucky and is managed by McCann and Pickles. CHGIS continues to be an active and useful venue for linking the research group and enabling its research.

The second task of the research group was the archiving of papers dealing with the history of GIS as background to defining specific questions and tasks for the team. McCann has worked to build this archive and has compiled a bibliography of contents for the research team, and the resultant selected reading list was supplied to all team members. This material provided the background reading for a workshop in Santa Barbara in September 1996. That workshop, held at Santa Barbara's Upham hotel, was attended by Curry, Goss, Mark, McHaffie, Miller, Pickles, and Varanka. The workshop included detailed discussions on the nature of the project, plans for establishing a formal archive for the History of GIS (to be located at the Library of Congress or the American Geographical Society), careful specification of research questions and tasks, and a workshop on research methods.

Ancillary activities related to this work are Mark and McHaffie's participation in the November GIS/LIS Conference, Pickles' short lecture course on GIS and Society, given to the Finnish National Post-Graduate Seminar the University of Turku, Nov. 6-7, 1996, and preparation of Pickles' manuscript on the history of Il9 for the forthcoming book edited by Longley, Goodchild, Maguire, and Rhind.

The CHGIS group outlined a series of central issues that guided its work, a set of specific questions that individuals seek to answer in their own work, and a plan of research topics to be undertaken over the next three years.

Kanawha Valley Study: GIS and Environmental Risk. Work on the Kanawha Valley Study is being carried out jointly at UK (University of Kentucky; Pickles) and WVU (Harris and Weiner). The bulk of resources have been directed to WVU to support preliminary research on this project. Resources allocated to UK are limited and are being used to continue that portion of the research that deals with the extent to and the ways in which geographic information and GIS specifically are deployed to deal with issues of environmental hazard and risk in the Kanawha Valley. The delay in receiving subaward funding for the project (funds not available until October, 1996) affected the start-up time of the Kanawha Valley project, where small funds were needed for field research but were unavailable until October.

A graduate research assistant, one of the two who did the original study on which this project is based, has been working to re-establish contacts with primary actors and institutions in the valley, to establish an organizational flow-chart, and to carry out interviews with individuals and organizations in the valley. Three trips to the valley have been made and the progress of the work is satisfactory. On the first trip, contact with the WVU researcher was established and initial coordination worked out. On the second trip we were fortunate to have Jeff Popke—second author on the original report on which this research is based—available for interviewing in the valley. Moreover, the trip corresponded with a major coordinating meeting of organizations responsible for hazard mitigation in the valley.

Risk, Decision-Making, and Local Information (Minnesota). The NCGIA Initiative 19 project at the University of Minnesota consists of two parts: (1) building a risk assessment model for the Twin Cities that integrates geodemographic, institutional, and hazardous materials information; and (2) determining how neighborhood organizations might utilize GIS technologies in decision making and conflict resolution. The goals of the project for year 1 included gathering all census data, including TIGER files with current address ranges, TRI and related data (such as Petrofund and Superfund sites), building a neighborhood database, and acquiring /developing and testing a plume dispersion model. Two RAs were hired for this purpose: one since August 1 1996, with funds from Neighborhood Planning for Community Revitalization headquartered at the University of Minnesota; the other since September 15, funded by NCGIA. Additional activities in year 1 included developing contact with neighborhood groups and helping them identify the utility of GIS for their needs.

Community GIS in Rural Areas (Buffalo). John B. Krygier's research focuses on visual representation within the context of geographic information technologies, and in the relations between landscape, regional, social and historical geography and visual representation within the new technologies. Geographers are critically examining the social impacts of GIS, mapping, and information technology. Krygier has recently begun a pilot project investigating marginalized places and groups, and how such places can be presented

and re-presented on the World Wide Web. Issues include the linking of new information technologies (the internet, WWW, hypermedia), and application spatial data and analysis to geographic issues surrounding economically and socially marginalized places and people.

Initiative 20: Interoperating GISs. This new initiative was approved in principle at the June, 1995 meeting of the Board, and in detail at the June, 1996 meeting. Its intent is to study the fundamental theoretical and conceptual problems underlying the concept of GIS interoperation, and thus to provide the necessary scientific underpinnings to current efforts to establish GIS interoperability through efforts such as the Open Geodata Interoperability Specification (OGIS). The specialist meeting will be held in December, 1997.

Karen Kemp spent the month of October 1996 in Canberra, Australia, working with colleagues at the Australian National University and CSIRO, continuing research into integrating traditional spatial models of the environment with GIS, research which will contribute to I20.

Initiative 21: Formal Models of Common-Sense Geographic Worlds. NCGIA Initiative 21 focuses on the cognitive aspects of geographic space and computational methods and models of geographic concepts as well as the design of systems that integrate the ideas of naive geography. In the long run, the models developed from this research can be used to refine GIS technology so that GISs can be made to 'reason' or 'think' like a human expert.

The multidisciplinary Steering Committee for the Initiative includes the following members:

Roger Downs, Geography, Pennsylvania State University
Andrew Frank, Geoinformation, TU Vienna, Austria
Janet Glasgow, Computing and Information Science (AI), Queen's University, Canada
Pat Hayes, Computer Science (AI), University of Illinois
Dan Montello, Geography, Santa Barbara
Barry Smith, Philosophy, SUNY Buffalo
Barbara Tversky, Psychology, Stanford

The NCGIA Initiative 21 Specialist Meeting was held from October 31 to November 2, 1996, in San Marcos, Texas. This meeting, which was attended by 42 researchers from North America and Europe, was organized and led by David Mark (NCGIA-Buffalo) and Max Egenhofer (NCGIA-Maine). The Department of Geography, Southwest Texas State University and UB Geography Graduate F. Benjamin Zhan served as its local hosts. There were 48 applicants for this meeting, the largest number ever to submit to an NCGIA Specialist Meeting, and the backgrounds of the attending participants included such diverse fields as psychology, philosophy, computer science, engineering as well as geography.

Initiative meeting sessions focused on: the role of modeling of common-sense knowledge in artificial intelligence, the nature and definitions of common-sense geography, the role of common-sense geography for GIS, and how to formalize the representations of common-sense theories.

The outcomes of the meeting include a technical report, currently in preparation, as well as the definition of a set of short and long term research goals. The research agenda defined by the specialist meeting included 49 researchable questions. The questions may be categorized under the following themes:

GIS and other Applied Topics (17 researchable questions)
Human Subjects, Developmental (9 researchable questions)
Geography/AI/Philosophy/Mathematics (23 researchable questions)

A more complete report on the meeting and the research agenda it established will appear in the Report on the Specialist Meeting, currently in preparation. Future activities include the following:

- A workshop on the "History of the Concepts of Space", organized by Barry Smith, (Philosophy, Buffalo), to be held on the University at Buffalo campus April 18-19, 1997. It will include I21 talks by Smith, David Mark, Max Egenhofer, Michael Curry, and Leo Zaibert.

- A full day of sessions on cognitive geography topics at the upcoming annual meeting of the Association of American Geographers, April 1, 1997

- A possible panel to be held in conjunction with COSIT '97 (Pittsburgh, PA October, 1997)

- Establishment of a Geographic Ontologies Web site at Buffalo (under construction)

- A study to relate collections of feature types, feature codes, or entity types from geocartographic data standards such as SDTS, and evaluate them as claims about geographic ontologies (Mark, Smith, Cohn, Egenhofer).

- Preparation of a paper on the relations between Naive Geography, academic geography, and GIS, (Mark, Smith, Egenhofer, and perhaps others).

Other research activities not connected directly with Initiatives

Human Capital Research. Munroe Eagles conducted background research on social capital and neighborhood organization in Buffalo, NY in the Summer of 1996, and has been working in cooperation with Hugh Calkins and Pamela Beal (School of Management) to develop a study of Block Groups in the University District region of the City of Buffalo. The investigators have subsequently prepared a proposal for external funding of a continued study of block groups (submitted in February, 1997). Eagles has also continued to work on preparing an edited book of papers derived from the 1995 conference "GIA and Human Capital Research".

Other work, which falls under the dual umbrella of Human Capital and Initiative 19 research, includes Sharmistha Bagchi-Sen's work on income inequality and occupational segregation based on various demographic and geographic variables. Meghan Cope's study of the devolution of welfare to states and localities, and the participation of different populations in public assistance programs also credits the NCGIA Human Capital and Initiative 19 programs. Products of this work include a book chapter (listed below). Cope has received development funding from the NCGIA at SUNY Buffalo for additional work in this area, and in December was awarded additional development funding from the Faculty of Social Sciences for related work on the roles of non-profit organizations in providing welfare services, shaping labor markets and building social capital.

Spatial Technologies, Geographic Information and the City. Yongmei Lu, PhD student at SUNY Buffalo, is researching the social implication of unequal access to online information, and the possible role of GIS in reducing the gap between the "informational rich and poor". Ms. Lu is exploring the barriers people face in accessing online information, the influence of unequal access to information on urban social and spatial patterns, and has developed a GIS toolbar that could potentially be used to improve the ability of people to access information on the Internet. A paper based on this work, "Improving the Accessibility to Information on Internet" was accepted for the September NCGIA conference on Spatial Technologies, Geographic Information and the City. This activity could also be seen as part of NCGIA Initiative 19.

Other Research at Buffalo. Other research at the Buffalo site includes efforts, led by researcher Sam Cole and graduate assistant Emil Boasson, to reconcile geographical data compiled in various coordinate systems into one coordinate system. The goal of the project is to find a simple method that can be used by planners in regions and countries where different data are available at different scales, projections and quality. MapInfo was the software used.

Jean-Claude Thill has been working on developing a network-based model of economic impact of public recreation facilities. Projected products of this effort include a research paper to be submitted to *Geographical Analysis* or *Socio-Economic Planning Sciences*, and a presentation of research results at JEC-GI 97, Vienna, Austria.

Graduate student Craig Hanson has been working with researcher Ling Bian on the theory and methods of data simulation. This research is specifically connected with interpolation procedures, but may be useful in any situation when artificially generated data may be required as a control group.

Other Research at Maine. Scott Overmyer, Assistant Professor of Management Information Systems, University of Maine College of Business, looked at ways to "spatialize" corporate information assets, so that the data is more "available" to executives doing strategic information system planning. To approach this goal, he developed a strategy for georeferencing data from non-geographic sources, and representing the data as a spatialized information architecture. He also worked on integrating GIS into his management information systems and decision support systems courses.

During 1996, Nectaria Tryfona worked on formalisms of models to assess object and relation homeomorphisms of spatial objects at different levels of detail (generalization topic based on the 4 intersection model and on graph theory) and on the extension of the 9-intersection model to capture topological relationships in 3-dimensional space. Specifically, during the months Jan-Jun 1996 she worked on computational models to assess consistency among homogeneous and heterogeneous networks. During the months June-August 1996 she worked on the derivation of binary topological relationships between simply-connected volumes, regions and lines in 3-D. She is also working on the issue of interoperability of GIS; conceptual modeling of geographic applications; and designing geographic applications with specific models and tools.

B. Education

1. General

NCGIA education activities continue to serve educators and others involved in GIS-based education in the universities, colleges, and K-12 schools. The most visible projects of 1996 which extend into 1997 and beyond are a series of GIS Core Curriculum development efforts. The newest among these, the GIS Core Curriculum for Technical Programs, is being developed under an National Science Foundation grant as part of our Community College Project. Our five-year Secondary Education Project for K-12 GIS is still one of our active projects, but our focus has shifted to the two-year college project. We continue to organize conferences that support GIS education at all levels.

2. The new on-line Core Curriculum in Geographic Information Science

In 1996, development of the new Core Curriculum in GIScience (the GISCC) began. The GISCC will incorporate many of the best elements of the original Core Curriculum while taking advantage of the digital innovations provided by the WWW. Like the original, it is a joint project of the international community of higher education GIS educators, but this time the opportunity for involvement is even greater. Beginning with an entirely new outline, more than 170 units have been designated and will be written in 1997. Like the original, each unit is structured as a textual outline of the critical information which might be included in a lecture, practical exercise or other instructional unit based on this topic. However, since the materials will be on the WWW, color graphics and pointers to other on-line instructional materials are included.

More than twenty section editors now oversee the assignment of units to appropriate authors and the peer review process which each unit now undergoes. Following the peer review, all units will be posted on the WWW for public review and comment (via email). In this way, the materials will continue to evolve for some time. The unit outline is constructed in a tree, so that new units can be added as needed while links between separate branches and individual units can be created where appropriate.

3. Remote Sensing Core Curriculum

Work continued on the NCGIA Remote Sensing Core Curriculum (RSCC). The RSCC represents a logical extension of the NCGIA's educational activities towards establishing curriculum materials for geographic analysis education. The RSCC developed as an outgrowth of NCGIA's Initiative 12, "The Integration of Remote Sensing and Geographic Information Systems", and particularly the interest of Arturo Silvestrini, President of EOSAT. The project seeks to develop educational materials to advance scientific understanding of the field of remote sensing for the large community of environmental engineers and scientists, resource planners and managers, and geographers in colleges and universities nationally and internationally. Lecture materials, outlines, exercises to build on theory and technique, and applications encompassing a robust set of real-world uses will be provided through a network of researchers and educators specializing in key areas of remote sensing. Materials will be distributed via the World Wide Web, CD-ROM, and hardcopy formats.

4. GIS Core Curriculum for Technical Programs

NCGIA has been awarded a two year grant from the National Science Foundation Advanced Technological Education (ATE) Program to develop a core curriculum in GIS for two-year colleges. This GIS Core Curriculum for Technical Programs (CCTP) draws from the Core Curriculum in Geographic Information Science, but is focused towards technician training in the community colleges, thus approaching the information more from what the practitioner needs to be able to do, rather than what they need to know. Like the other Core Curricula, it is being developed as a World Wide Web based resource. It will include a number of components useful to GIS instructors in technical programs and additional links to external resources. The CCTP project began in summer 1996 with a one-week Working Session in which fourteen GIS instructors and other experts developed a framework for the core curriculum. A website has been

established and in 1997 and the beginning of 1998, the curriculum will be written, tested, revised, and publicized.

5. Community College Project

The two-year colleges are an important and rapidly growing sector for GIS education and training. GIS courses and programs exist or are being developed in nearly one hundred colleges in North America. The NCGIA continues to support efforts to provide GIS learning experiences in the colleges through the conferences and curriculum efforts listed above. In addition, Steve Palladino, the NCGIA Education Projects Manager, is keeping a master list of community colleges with GIS instruction and parties interested in community college GIS.

6. Secondary Education Project

The Secondary Education Project (SEP) continues to function as one of the sources of information on activities and materials for using GIS in the pre-collegiate classroom. This includes occasional outreach efforts by the NCGIA sites to schools in their respective regions.

See the Education Program web page for more information on this and other NCGIA Education Activities (http://www.ncgia.ucsb.edu/education/ed.html).

7. Activities at Maine

In January 1996, the Department of Spatial Information Science and Engineering's Spatial Horizons Fall workshops continued with two sessions for high school students and two additional sessions for high school teachers. The Fall workshop included learning activities on world wide web homepage construction and on geographic information systems. Beginning in March, the Spatial Horizons Spring workshop program switched to hands-on activities exploring Global Positioning Systems (GPS) and enhancing remotely-sensed images.

The Spatial Horizons workshop program was developed and run by Harlan Onsrud and Sharron Macklin, graduate student. The GPS Orienteering activities and lectures were provided by Jonathan Stewart and Paul Rosenboom, both graduate students. Assistance in conducting the workshops was provided by Kate Beard, Peggy Agouris, and the following graduate students: Vyjayanti Sharma, Boon Witchayangkoon, Nancy Marth, Nancy Blyler, Mike Coan, Mike Paluzzi, Kelly Zeiner, Bhesham Ramlal, Jeanne Timmons, and Daniel Hagopian.

In addition to workshops provided for school groups during the academic year, summer sessions were held as part of the University of Maine Young Scholars (for gifted high school students) and Technology in Education programs.

Attempting to meet the needs of the Maine business community, ArcView and Avenue software training workshops were created by Kelly Zeiner and Sharron Macklin working with Kate Beard. Nancy Marth provided editorial assistance.

The two-day "Introduction to ArcView" workshop was held twice in August with waiting lists each time. The one-day "Introduction to Avenue" workshop was also held twice. Continuing inquiries about these popular workshops motivated an October session led by Sharron Macklin and Nancy Marth. Future plans include additional workshops in 1997 after the materials are updated to the new ArcView GIS 3.0 version.

C. Outreach

1. Conferences (see the Initiative reports for additional Specialist Meetings)

Spatial Technologies, Geographic Information, and the City
NCGIA Santa Barbara and NCGIA Buffalo co-sponsored the research conference "Spatial Technologies, Geographic Information and the City". This conference, which was held in Baltimore, MD, September 9-11, 1996, was co-led by Helen Couclelis (NCGIA Santa Barbara) and J. Michael Batty (University College London, formerly of NCGIA Buffalo). Approximately 30 researchers attended.

Science-On-Line Antarctica Workshop
Hugh Calkins served as an organizer of the "Science-On-Line Antarctica Workshop", held in Tahoe City, CA, Sept. 23-26, 1996. Approximately 40 persons participated. The purpose of the workshop was to introduce GIS as a tool for researchers on projects involving the McMurdo Dry Valleys Antarctica LTER (Long Term Ecological Research) Site. This workshop was sponsored by a National Science Foundation grant to the Desert Research Institute (Project Director, Jordan Hastings).

Santa Fe conference
Continuing the tradition started in Boulder in 1991, NCGIA organized the Third International Conference/Workshop on Integrating GIS and Environmental Modeling in Santa Fe, NM January 21-25 1996. Over 100 papers were presented, and the conference also included workshops, special meetings, keynote presentations, and general discussion. Approximately 500 people participated, drawn from academia, the private sector, and government agencies. The attendance was particularly gratifying given that the meeting occurred in the midst of the 1995-96 government shutdowns.

The program, lists of participants, abstracts, and the full texts of papers can be found on the NCGIA web site under 'conferences'. In addition, NCGIA has published a CD of the conference proceedings—to order, contact the NCGIA Publications Office at the Santa Barbara site, 805 893 8224, FAX 805 893 8617, email ncgiapub@ncgia.ucsb.edu.

Second International Symposium on Spatial Accuracy Assessment in Natural Resources and Environmental Sciences (May 21-23, 1996, Colorado State University, Fort Collins, Colorado)
Over 260 participants attended the three-day symposium, representing over 20 countries throughout the world. The series is a direct outgrowth of NCGIA's I1 and I7, and Michael Goodchild was a member of the core organizing group. Each morning, one plenary speaker addressed accuracy issues in spatial data and analyses from either the geographic information system (GIS), spatial statistics, or remote sensing perspectives. A total of ninety-four invited and contributed papers dealing with various aspects of these topics were also presented in 24 concurrent sessions throughout the three days. A closing discussion of current trends and research directions in the field was led by a ten-member panel. The 728-page proceedings is available at no charge from Publications Distribution, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 240 W. Prospect, Fort Collins, Colorado 80526-2098 (Please reference RM-GTR-277 in your request). The third symposium is scheduled to be held in Quebec City in May 1998.

The Second International Symposium on GIS in Higher Education
GISHE '96, organized by NCGIA and Towson State University, was held in Columbia, Maryland, in September 1996. The theme for this symposium was "Expanding GIS Education through Technology and Outreach" and its purpose was to provide a forum for discussion of today's strategic issues in GIS Higher Education. Several plenary sessions, plus three parallel tracks of paper presentations followed by focused discussions, were held over 2 1/2 days. While most of the 140 participants came from US and Canadian institutions, people from the UK, Europe, Africa, Australia and New Zealand also attended. A group of local high school teachers and a number of community college instructors also attended. Separate one-day parallel tracks for each of these special audiences were provided.

Paper session discussions were recorded and carried forward to the final morning when a conference summary was prepared by the remaining participants. This summary along with the conference program, paper abstracts (including some outlines of talks actually presented) and a list of participants is posted on the conference website at http://www.ncgia.ucsb.edu/conf/gishe/main.html. Several papers have been chosen to appear in a special issue of *Transactions in GIS* planned for publication in late 1997. Planning for a Third International Symposium on GIS in Higher Education (GISHE '97) is underway.

California GIS Educators' Symposium

In addition to coordinating an international symposium for GIS educators (GISHE), NCGIA-Santa Barbara also organized a smaller symposium for California GIS Educators in August 1996. Forty representatives from the University of California, California State Universities, community colleges, private universities, and a high school, met for a day and a half in Santa Barbara to plan strategies for cooperation among GIS educators in different institutions. The outcome of this meeting can be viewed on http://www.ncgia.ucsb.edu/education/conf/CaGIS/CaGIS.html.

National Council for Geographic Education Annual Meeting

In November 1996 the National Council for Geographic Education held its Annual Meeting in Santa Barbara. The NCGIA Education Program was very involved in planning various aspects of this conference. NCGIA helped organize sessions on GIS, facilitated hands-on GIS workshops at UCSB, and hosted an NCGIA open house for conference participants.

EDGIS '96

The NCGIA, along with TERC and the National Council for Geographic Education (NCGE), organized a workshop of research specialists in the area of K-12 GIS education. EDGIS '96 took place in conjunction with the NCGE Annual Meeting held in Santa Barbara in November 1996. The researchers who participated worked to develop an agenda of key research issues for GIS use in the schools. The research agenda includes research needs in the areas of pedagogy, cognition, curriculum, and software.

Public Participation GIS (PPGIS) Workshop

As part of the activities under Initiatives 17 and 19, Maine hosted a small workshop July 10-13. Participants discussed the potential for a GIS oriented toward public participation, implementing many of the ideas discussed under the rubric of 'GIS 2' in I19, and involving collaborative participation. The workshop discussed requirements, user interface issues and other design considerations, and mechanisms for implementation. Participants included Michael Barndt, University of Wisconsin - Milwaukee; Kerry Brooks, Clemson University; William J. Craig, University of Minnesota; Michael L. Elliot, Georgia Tech; Michael Goodchild; Daniel B. Karnes, Dartmouth College; David Mark; Mark Monmonier, Syracuse University; Timothy Nyerges, University of Washington; Nancy Obermeyer, Indiana State University; and Michael Shiffer, Massachusetts Institute of Technology. Further information is available at http://ncgia.spatial.maine.edu/ppgis/ppgishom.html

Seventh Annual International Conference of the Atlantic Institute

The University of Maine Department of Spatial Information Science and Engineering and the NCGIA-Maine site co-hosted the "Seventh Annual International Conference of the Atlantic Institute", September 19-21, in Orono, Maine. The Atlantic Institute is an educational institute dedicated to advancing knowledge in the spatial sciences for the effective stewardship of the Earth's resources. Through exchange of ideas and information, the Institute promotes the development of techniques and tools for the efficient handling of geographically related data. Its principal goal is to promote closer ties among the geomatics and spatial information engineering programs of the University of Maine, the Universities of New Brunswick, and Laval University.

2. Visiting Fellows

I17 research group at Buffalo. A group of visitors assembled at the Buffalo site in July to work on Initiative 17 research. NSF Visiting Fellows in the group were: **Britton Harris**, Professor Emeritus,

University of Pennsylvania (July 20-23); **Michael Shiffer**, Massachusetts Institute of Technology (July 23), and **Marc Armstrong**, University of Iowa (July 18-25). Other visitors to the Buffalo site included, but not classified as visiting fellows were **Paul Densham** (University College London and Adjunct Asst. Professor, SUNY Buffalo) and **Karen Kemp** (NCGIA Santa Barbara) (July 22-23).

William Albert (Boston University)
Dr. Albert was at UCSB in the Fall of 1996 collaborating with Reginald Golledge and others on research in spatial cognition, in support of I21.

Larry Band (University of Toronto)
Dr. Band met with Chris Larsen, David Howes, Athol Abrahams, Gang Li, Ling Bian, Mike Woldenberg and David Mark. Dr. Band delivered the talk "Scaling Forest Productivity Simulation over the Province of Ontario".

Carol Bult (The Institute for Genomic Research)
Dr. Carol Bult is working with Kate Beard and Max Egenhofer at the National Center for Geographic Information and Analysis (NCGIA) at the University of Maine on the development of a Genome Spatial Information System. Before coming to NCGIA as a Visiting Scientist, Dr. Bult was a member of the Research Faculty and the Director of the Molecular Systematics Laboratory at The Institute for Genomic Research (TIGR) in Rockville, Maryland. She led the team that sequenced the entire genome of the methanogenic archaeon, Methanococcus jannaschii (Bult et al., 1996. *Science* 273:1058-1073). M. jannaschii was the first member of the domain of life known as the Archaea to be completely characterized at the DNA level. The Genome Spatial Information System (GenoSIS) project is an interdisciplinary effort to test if geographic and spatial information concepts and methodologies are useful for the visualization, discovery, and analysis of biologically significant aspects of genome spatial organization and structure. The NCGIA/UM team is collaborating with the genome bioinformatics research group headed by Dr. Janan Eppig at The Jackson Laboratory (Bar Harbor, Maine) on the development and implementation of GenoSIS. A proposal was submitted to the National Science Foundation (Biological Database Activities), to seek funds to continue the project.

Bin Li (University of Miami)
Professor Li was a visiting fellow at NCGIA Buffalo October 13-18, 1996. Professor Li had discussions with NCGIA members David Mark, Barry Smith, Ling Bian, Mike Woldenberg, David Zubin, John Krygier and Chris Larsen and several NCGIA graduate students. He also met with Prof. Aidong Zhang (Computer Science) and toured SUNY Buffalo's Great Lakes Center. While at Buffalo, Professor Li delivered the talk "Some Technical and Theoretical Issues in Designing Distributed and Component-based GIS"

Robert Raskin (UC Santa Cruz)
Dr. Raskin spent the first six months of 1996 at UCSB continuing research into spatial analysis methods on the sphere, and assisting in the development of the Spherekit module (see I15 report).

Timothy H. Robinson (National University, Heredia, Costa Rica)
The researcher spent the month of February 1996 at UC Santa Barbara. The primary objective of the research was to get a clear orientation on the structure and format necessary to create a relational hydrologic database of three centrally located and important watersheds in the populous Central Valley of Costa Rica. This analytical tool will be used to study and manage the conservation and sustainable use of potable water reserves into the next century.

Robert Rugg (Virginia Commonwealth University)
Dr. Robert Rugg, Professor, Dept. of Urban Studies and Planning, Virginia Commonwealth University, worked with Max Egenhofer under the NCGIA visiting scholars program, June 23-July 10, 1996.

Mauro Salvemini, University of Rome La Sapienza
Professor Salvemini visited NCGIA at Santa Barbara under a grant of the Italian CNR (Consiglio Nazionale delle Ricerche) for the period November 25 - December 15, 1996. He collaborated in development of GIS and education in GIS.

4. Collaboration with the European Science Foundation GISDATA program

The European Science Foundation GISDATA program was launched in January 1993 as a four year program of collaborative research with the support of fifteen member countries of the foundation. Its objectives are:

1. To enhance existing national research efforts and promote collaborative ventures overcoming European-wide limitations in spatial data integration, data base design and social and environmental applications.

2. To increase awareness of the political, cultural, organisational, and technical and informational barriers to an increased utilisation and inter-operability of GIS in Europe.

3. To promote the ethical use of integrated information systems, including GIS, which handles socio-economic data by respecting the legal restrictions on data privacy at the national and European level.

4. To facilitate the development of appropriate methodologies for GIS research at the European level.

5. To produce outputs of high scientific value.

6. To build-up a European network of researchers with particular emphasis on young researchers in the GIS field.

The program includes collaboration with U.S. scientists, through participation on the Steering Committee, in workshops and conferences, and through two jointly organized Summer Institutes for young scholars.

In August 1994, the National Center for Geographic Information and Analysis was awarded $40,000 to support collaboration in the program by U.S. scientists, and NSF provided continuing support in FY95 at $30,000.

During 1996 the final three specialist meetings of the program were held. Details of the three meetings held in 1996, with US participation, follow:

Formalizing and Representing Spatial and Temporal Change in Spatial Socio-Economic Units (Navplion, Greece, 22-26 May, 1996)

The meeting brought together 19 scientists from Europe and the US ranging from university professors to PhD candidates and with different scientific backgrounds, i.e. from philosophy, political sciences, human geography, and computer sciences to cadaster, civil engineering, urban planning, and forestry. It was hoped that the diversity of background would allow commonalities to be seen in the topic which none of the disciplines concerned could approach independently. The goal of the meeting was to find a common ground for classifying and presenting change of spatial socio-economic units (SSEUs) among different research perspectives. One of the key concepts is the classification of change in two forms: change of objects of interest ('life') and change in the position or geometric form of these objects ('motion'). Stuart Aitken of San Diego State University was the NSF-sponsored US participant. A book will be edited by Andrew Frank, Jonathan Raper, and Jean-Paul Cheylan and published by Taylor and Francis.

GIS and Health in Europe (Gustavelund, Finland, 29 May - 2 June 1996)

> This meeting aimed at fostering cross-national, multidisciplinary research in this field and at developing a research agenda for the coming years. Papers were presented by 15 speakers representing the fields of geography, epidemiology, environmental sciences, public health, and biosciences. The presentations and in-depth discussions at the meeting highlighted the rapid development of inferential statistics for analyzing clustering in the presence of uneven population distributions. The methods have been developed mainly in health statistics but the application potential in other fields of inquiry is evident. A wider adaptation of inferential spatial statistics requires that they are integrated into GIS, including desktop GIS, and that adequate training and education are provided. Geoffrey Jacquez (BioMedware Inc) and Gerard Rushton (University of Iowa) were the US NSF-sponsored participants. A book will be edited by Anthony Gatrell and Markku Loytonen and published by Taylor and Francis.

Geographic Information: The European Dimension (Buoux, France, 8-12 May, 1996)

> This meeting involved representatives from academia and the private sector with a stake in geographic information and observers from the European Commission and Eurostat, and focused on the integration of data at the European level. This is one of the central concerns of the GISDATA program as a whole, as the lack of good quality European-wide data was perceived as one of the main barriers to the development of social science research in Europe by an ESF-ESRC report in 1991. Harlan Onsrud was the US NSF-sponsored participant. A book will be edited by Ian Masser and Peter Burrough and published by Taylor and Francis.

Michael Goodchild represents the U.S. on the GISDATA Steering Committee. Ian Masser (University of Sheffield), coordinator of the GISDATA program, is a member of the NCGIA Science Policy Committee.

The GISDATA program includes two joint NSF/ESF Summer Institutes for Young Scholars. The 1995 Institute took place July 26 to August 2 at the Wolfe's Neck Center of the University of Southern Maine, near Freeport, ME. A report of the second Summer Institute held in Berlin in 1996 follows.

1996 International Young Scholars Summer Institute in Geographic Information (report by Adrijana Car, Technical University of Vienna)

The GISDATA initiative of the European Science Foundation and NCGIA organized a Summer Institute in geographic information which took place in Villa Borsig, Berlin, Germany, from July 24 to August 1, 1996. This Summer Institute was the second of its kind, after the one held in Wolfe's Neck, Maine, USA, and brought together 32 'early career scientists' (at the PhD level) and 14 senior researchers from the field of geographic information science from all over Europe and the US. The young scientists were scholars, selected according to the review of their submitted contributions. They spent eight days working together. In numerous discussions the participants exchanged their experience. This was especially valuable for the young scholars as they received feedback on their work. Another aspect was to become acquainted with both the living legends of GIS research, and with young scientists of similar interests.

The program consisted of keynote speeches and workshops given by the senior researchers, and papers given by the young scholars. Keynotes gave an overview and summary of actual research directions in geographic information science. The range of topics covered: (i) philosophical, societal and aspects of ethics and law, and the role of GIS in decision making processes; (ii) conceptual aspects: quality, modeling space and time; (iii) application areas, like global change, health, urban planning and remote sensing. Workshops focused on the use of research results in industry, geoinformation resources on the Web and how to publish in academia. The papers presented by the young scholars reflect their specific research interests. Topics are wide

spread covering (i) cultural, economical and conceptual aspects of GIS; (ii) quality assessment, spatial analysis and spatial reasoning; (iii) visualization, user interface design, use of remote sensing for modeling and analysis for GIS. These papers were presented in three parallel sessions, and the chairmen were requested to give an overview of each session during a daily 'happy hour'.

The second part of the Summer Institute was dominated by a competition in writing (hypothetical) research proposals. Each of six groups submitted a proposal to the review committee and gave an oral presentation to the plenum. Writing a research proposal from the scratch was a valuable experience for young scholars for various reasons. Scholars experienced team work in an interdisciplinary and international environment. Senior researchers, attached to each group, advised how to manage a project and how to set up a proposal. Scholars' inputs were creative ideas, concepts, methods and tools. They gave their vision about future research directions, and some nights were spent in front of computers.

Villa Borsig, in a park at Lake Tegel, provided a pleasant working environment and supported the social part of the Summer Institute. Social events helped to accomplish all the tasks of the Summer Institute successfully. Field trips like a boat tour through Berlin, visit to Potsdam and Berlin provided pleasant breaks. But the highlight of the Summer Institute was the award of the group with the best proposal. The overall celebration of this great event ended with a barbecue in the Villa Borsig's garden.

Organizers did their best to make the stay of participants as pleasant as possible. Thanks primarily to Massimo Craglia from GISDATA, Harlan Onsrud from NCGIA, and the local organizing staff! Proceedings of both Institutes will be published by Taylor and Francis.

Although this was the last of the GISDATA-NCGIA Summer Institutes, new opportunities will be available next year through the GISDATA Euroconference on GIS and the Social Sciences.

5. Collaborative Grants Program

In the 1993 renewal of the NCGIA Cooperative Agreement, funds were set aside to support collaborative projects with other institutions outside the NCGIA consortium. The program requires non-NSF matching by the collaborating institution. Proposals are reviewed by NSF as supplemental awards. In 1996 two previously established projects continued, and two more projects began.

Predator-Prey Modeling of Fish Populations in 3-Dimensional GIS: NCGIA Buffalo and the Great Lakes Center at Buffalo State College.

This project is in collaboration with Stephen Brandt at the Great Lakes Center, Buffalo State College. The PIs are Hugh Calkins, Joseph DePinto, and Ling Bian at the NCGIA Buffalo site.

Goals and Objectives
1) To identify a framework for the existing two-dimensional predator-prey models using GIS as the basis for data analysis, model estimation, and scientific visualization.

2) To extend the two-dimensional representation to three-dimensional data.

3) To explore the spatial aggregation problem within the three dimensional framework, for both two- and three-dimensional data sets and models.

4) To design and apply appropriate predator-prey models that incorporate a three dimensional space, interaction between fish populations and the three dimensional habitats, the temporal change of the habitats, and the dynamics of the fish populations.

Research Activities

Objective 1 was completed in the first six months of the year. Objectives 2 and 4 were the two major tasks that were undertaken at the NCGIA Buffalo site during the second six months. Objective 3 will be conducted by the collaborator institute.

The task of interpolating prey density is part of the overall goal of implementing a fish growth model into a three dimensional GIS environment. The data currently available are collected through a series of distant, two dimensional transects in Lake Ontario. The transects are arranged in both north-south and east-west directions, so can be considered to be quasi "three dimensional". This data layout is unique in comparison to more commonly seen three dimensional data collected for research in geology, hydrology, and atmospheric science. The primary focus of this task is to identify the optimal method of interpolation to generate a continuous, three dimensional prey data set. Geostatistical and GIS methods were used to analyze the data. The preliminary examination indicated that the spatial pattern of prey density is complex, in both continuous and discrete nature. Based on these observations, different spatial interpolations were experimented with. A combination of conditional simulation and three-dimensional kriging is expected to be adequate in depicting the spatial pattern of the prey fish density.

A second part of Objective 2 is to interpolate water temperature and zooplankton data. Both data are inputs to fish growth modeling, providing information regarding habitats and food availability. These two types of data are sampled at the same time and location with the prey data but by a different method. The resultant sample data display a undulating pattern within each transact, which poses a challenge for spatial interpolation. Linear, inverse distance, and kriging methods are used to interpolate each transect in order to generate a series of continuous, two dimensional data sets. Different search strategies, diel sampling, and isotropies were applied to the interpolations. Cross validation measurement of mean absolute error, mean squared error, and minimum and maximum error are used to compare accuracy between interpolations. This study is in progress and is expected to complete in Spring, 1997. The expected output of this study is a Master's thesis and a manuscript.

Under Objective 4, we will extend the current two dimensional, static fish growth models to a more realistic, three dimensional framework. The three dimensional data interpolated under Objective 2 will be used in this study. An object-oriented framework will be used, in combination with a foraging and a bioenergetic model, to simulate the growth of the fish population. With the simulation, the study is intended to implement the behavior of individual predator fish in their selection of habitat and their movement in the three dimensional environment. The study will also simulate the temporal change of the habitats, and the interactions of the fish populations with the habitats, and the dynamics of the fish populations. Results of this work are expected to contribute to the effort of enhancing the spatial analysis in three dimensional and temporally dynamic environments, which has been identified as a weak aspect in current GIS. Currently this study is in the literature search and system design stage. The design is expected to complete in early Spring, 1997 and then implementation of the system will begin.

Integration of Remote Sensing and GIS, Assessment of Land Cover Change and Regrowth in a Northern California Forested Ecosystem. NCGIA Santa Barbara and the University of Washington

As a part of NSF-sponsored joint research between the NCGIA and outside institutions, a proposal was submitted to integrate GIS into a study of temporal changes in land cover and regrowth in a mixed evergreen forested region of northern California. The primary goal of the research is to assess the success of conifer regeneration in a watershed within the Six Rivers National Forest using remote sensing and to evaluate environmental, biotic and anthropogenic factors that may have influenced regrowth success using GIS.

As a part of a research project at the University of Washington, collaborators at that institution have assembled an extensive satellite-based data set consisting of a 21 year time series of Landsat MSS, 10 year of Landsat TM and one full-season data set of MSS starting in August of 1987. These data have already been co-registered and inter-calibrated. Considerable supporting geographical information

including digital elevation data, soils maps, seral stage maps and vegetation associations, assembled by the US Forest Service, have been integrated into an ARC/INFO database. Forest Service stand treatment histories have also been integrated into the data base. These histories consist of more precise logging data including month of cut, method of clearing, method of burn, and extent of replant. The resulting data set represents one of the most complete temporal records of land use for the Pacific Northwest.

This research is designed to contribute to this multi-temporal study by integrating GIS into the research program to study regrowth. Methods employed combine remotely-sensed analysis and geographical analysis using ARC/INFO. Remotely-sensed analysis will focus on multitemporal image classification and the establishment of temporal profiles for regrowth. An image processing approach based on the use of spectral mixture models has been used to develop consistent land cover indices that describe the pattern of regeneration over time. The accuracy of the classification will be evaluated through comparison to existing vegetation maps and field notes taken on-site in April 1996; a second site visit, tentatively planned for April 1997, will provide a final assessment of the classification.

Spatial and temporal relationships have been used to correct Forest Service cut data and will help improve classification accuracy. Regeneration success will be evaluated by comparing regrowth across the study area to a temporal profile of regrowth under optimal conditions. This optimal growth profile will be developed from the imagery in conjunction with published growth patterns and confirmed by a Forest Service vegetation regrowth model specific for the area: System One. Models of regeneration based on optimal growth will be used to assign apparent stand age, then compared to absolute stand age determined from the GIS to locate areas of substandard regeneration. Environmental, biotic and anthropogenic factors will be evaluated with respect to regrowth success through GIS. These results will form the basis of thesis research for Charles Kiedman and are to be presented at the ACSM-ASPRS Annual Convention in Seattle in 1997.

6. University Consortium for Geographic Information Science

Since 1992, NCGIA and its Board of Directors have been instrumental in instigating the formation of a national consortium of universities committed to research in GIS and geographic information analysis. A founding meeting was held in December 1994, and in 1995 an organization known as the University Consortium for Geographic Information Science (UCGIS) came into being. By its first annual meeting in Nashville in November 1995, close to 30 institutions had made the necessary initial commitment to become full members, including the three NCGIA institutions. Karen Kemp serves as a member of the Board of Directors. The first research meeting of the consortium was held in Columbus, OH in June 1996. Further information can be obtained at http://www.ucgis.org.

7. Technical Papers published

96-1: Image Registration using Multiquadric Functions, the Finite Element Method, Bivariate Mapping Polynomials and the Thin Plate Spline, by David N. Fogel, UCSB, and Larry R. Tinney, DOE Las Vegas, reports on an evalution of several methods of image-to-image registration using control points.

96-2: Algorithms for Hierarchical Spatial Reasoning, by Dimitris Papadias and Max Egenhofer, U. Maine, examines two types of inference for reasoning about spatial relations using multiple local frames of reference organized in aggregation hierarchies.

96-3: A Review of Spatial Population Database Design and Modeling, by Uwe Deichmann, UCSB, an overview of issues and options for the development of population related databases, including discussion of critical demographic variables required for integrated spatial analysis and modeling approaches for reconciling population data with other geographically referenced databases.

96-4: Creation of a Comprehensive Managed Areas Spatial Database for the Conterminous United States, by R. Gavin McGhie, UCSB, describes the methodology employed and problems encountered in creating the Managed Areas Database (MAD), a GIS database containing spatial extents for all types of managed areas including land held by federal, state, tribal and private agencies and organizations.

96-5: Research Initiative 15: Multiple Roles for GIS in US Global Change Research - Report of the Second Specialist Meeting, by Michael F. Goodchild and John E. Estes, UCSB, Kate Beard, U Maine, and Tim Foresman, U Maryland-Baltimore County, summarizes the informal presentations and discussions held on advanced geographic data models for global change research and the meeting's conclusions.

96-6: Critical Issues in GIS-Based Educational Module Development: NCGIA's ArcView-based *Color Your World* Module, by Steve Palladino and Paul Van Zuyle, UCSB, provides a framework for the development of GIS based education modules for K-12 schools, discusses critical design and process issues.

96-7: GIS and Society: The Social Implications of How People, Space, and Environment are Represented in GIS - Scientific Report for the Initiative 19 Specialist Meeting, by Trevor Harris and Daniel Weiner, West Virginia U, summarizes the meeting discussions and outlines four continuing research projects.

96-8: Spatial Theory for the Integration of Resolution-Limited Data, by Beat (Bud) P. Bruegger, Swiss Federal Institute of Technology, addresses the integration of data sets of different levels of resolution and different formats (i.e. raster and vector).

96-9: Conference on Object Orientation and Navigable Databases: Report of the Meeting, by Richard Church, Thomas Cova and Michael Goodchild, UCSB, and Ramez Gerges, Caltrans, reports on the conference objectives, discussion and conclusions. Includes a participants' list and background papers presented.

96-10: Spatial Technologies, Geographic Information, and the City, compiled by Helen Couclelis, UCSB, is a research conference report, includes an outline for a national research agenda.

96-11: Modeling Behavior of Geographic Objects: An Experience with the Object Modeling Technique, by Nectaria Tryfona and Dieter Pfoser, U Maine and Thanasis Hadzilacos, University of Patras, Greece, presents the semantics and graphical notation for a prototypical object-oriented model for the conceptual design of spatial databases supporting semantic interoperability**.**

96-12: GIS Laboratory Exercises: Introduction to GIS, 2nd edition, by Jeremy Taylor, Jane Fletcher, and Karen Kemp, UCSB an update of Report 91-12 with data and exercises for introductory GIS courses, written for use with *Idrisi for Windows 2* and *Arcview 2.* NOTE: Idrisi data is available from NCGIA via ftp, ArcView data is part of the standard software installation.

CD-ROM: Proceedings of The Third International Conference/Workshop on Integrating GIS and Environmental Modeling (Santa Fe, NM, Jan 21-25, 1996), is organized as a complete record of the conference, including the program and the full text of papers, plus abstracts of posters and workshops, and the list of attendees. Requires a WWW browser, for Windows 95 and NT, Unix and Macintosh computers.

Other NCGIA publications added January - December 1996:

Closing Report for Initiative 9
Closing Report for Initiative 13
Closing Report for Initiative 14
Annual Report Year 7 (January 1, 1995 - December 31, 1995)

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. A meeting was held in Maine in June, but no December meeting was held because of the impending changes to the structure of NCGIA, which include dissolution of the Board. At the June meeting the Board members were:

Ronald Abler (Association of American Geographers), Chair
Prue Adler (Association of Research Libraries)
Lawrence F. Ayers (Intergraph Corporation)
Jack Dangermond (ESRI)
Susan Hanson (Clark University)
Lawrie Jordan III (ERDAS)
Malvin H. Kalos (Cornell University)
Kija Kim (Harvard Design Mapping)
Annette Krygiel (Central Imagery Office)
T.R. Lakshmanan (Bureau of Transportation Statistics)
Joel Morrison (Bureau of the Census)
Eric Sheppard (University of Minnesota)
John Sprague (Washington University)
Peter Thacher (World Resources Institute)
Giovanni Wiederhold (Stanford University)
Cort Willmott (University of Delaware)

J.W. Harrington of the National Science Foundation also attended the June 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. On June 30, 1996 the members were Michael F. Goodchild (Director); Helen Couclelis (Associate Director, Santa Barbara); David Mark (Associate Director, Buffalo); Max Egenhofer (Associate Director, Maine); and Harlan Onsrud (Chair, SPC).

Under the new NCGIA structure, effective 1/1/97, there will be a Director at each site (Keith Clarke at Santa Barbara, David Mark at Buffalo, and Max Egenhofer at Maine), a Chair of the Executive Committee (Michael Goodchild), and an Assistant Director (Karen Kemp).

Scientific Policy Committee. The Scientific Policy Committee (SPC) held formal meetings in Maine in June 1996. 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 on June 30, 1996 included Waldo Tobler (Santa Barbara; NCGIA Senior Scientist); John Estes (Santa Barbara); Munroe Eagles (Buffalo); Hugh Calkins (Buffalo); and Kate Beard (Maine). SPC meetings are also attended by selected members of the Board of Directors.

The Science Policy Committee will be disbanded on the introduction of the new NCGIA structure, effective 1/1/97.

Personnel changes. In May, Ross MacKinnon resigned his position as Buffalo's Dean of the Faculty of Social Sciences to join the University of Connecticut as Dean of the Faculty of Arts and Letters. D. Munroe Eagles was promoted to the position of Associate Dean effective June 13, 1996, and received a two year appointment as Adjunct Associate Professor of Geography. New Members of the NCGIA at Buffalo are: John Krygier (joined Geography, August 1996), Jean-Claude Thill, (joined Geography, August 1996),

Barry Smith (Philosophy) and Stephen Hart (Sociology). Ezra Zubrow received a 4 month Leverhulme Fellowship from the University of Bristol, beginning in October, 1996.

Paul J. Densham has been promoted to Reader in Geography, University of London, with effect from 1 October, 1996.

At Santa Barbara, Michael Goodchild received the Intergraph Award from the American Society of Photogrammetry and Remote Sensing (with G.J. Hunter); the Association of American Geographers Award for Distinguished Scholarship; and the Horwood Critique Prize from the Urban and Regional Information Systems Association (with G.J. Hunter). Dan Montello was elected Chair of the Environmental Perception and Behavioral Geography Specialty Group of The Association for American Geographers (April 1996).

Dr. Yves Dennebouy, Senior Assistant, EPFL/Computer Science Dept./Database Lab, Lausanne, Switzerland, joined the NCGIA at the University of Maine as a Visiting Research Associate for a one-year term, effective April 1996.

3. EXTRAMURAL SUPPORT

A. Grants and Contracts Awarded as of 12/31/96

CALSPAN-UB RESEARCH FOUNDATION, $28,881, "Research on Building an Accident Data Base, Developing a Probabilistic Model, and Identifying Geographical 'Hot Spots' for the ACN Project", 2/1/96-1/31/97, PI's: Batta, Rogerson.

DESERT RESEARCH INSTITUTE (Subcontract from National Science Foundation), $6,500, "Pre SOLA Planning Workshop", 8/1/96-3/31/97, PI: Calkins.

ERIE COUNTY WATER AUTHORITY, $48,782, "AML Programming for Erie County Water Authority", 1/1/96-12/31/96 (renewal), PI: Calkins.

NASA EARTH SYSTEM SCIENCE FELLOWSHIP PROGRAM, $22,000, "Estimation of Human Population Parameters with Nighttime Satellite Imagery (DMSP) and GIS", 9/01/96-8/31/97, PI: Roberts.

NATIONAL SCIENCE FOUNDATION, $35,000, "A Data and Information Management System for the Gulf of Maine", 1/1/96 - 12/31/96, PI: Beard.

NATIONAL SCIENCE FOUNDATION, $35,000, "Worlds of Information: the Geographic Metaphor in the Representation of Non-Spatial Information", 7/1/96-12/31/97, PI: Couclelis.

NATIONAL SCIENCE FOUNDATION, $9,888, "Doctoral Dissertation Research: Collaboration and Innovation in the Commercial Geographic Information Systems Industry", 5/1/96-12/31/96, PI: MacPherson.

NATIONAL SCIENCE FOUNDATION (Award Transferred from University of Georgia), $85,078 (transferred $5,279), "Modeling Constraints in Travel Destination-Choice Behavior", 91/93-8/31/97, PI: Thill.

NATIONAL SCIENCE FOUNDATION, $480,000, "Multi-Modal Spatial Querying", 1996-2000, PI: M. Egenhofer and S. Overmyer.

NATIONAL SCIENCE FOUNDATION, $33,703, "Integration of Remote Sensing and GIS, Assessment of Land Cover Change and Re-growth in a Northern California Forested Ecosystem". 4/01/96-3/31/97, PI's: Goodchild, Roberts.

NATIONAL SCIENCE FOUNDATION, $188,469, "A GIS Core Curriculum for the 2-Year College", 7/1/96-6/30/98, PI's: Goodchild, Kemp, Palladino.

NATIONAL SCIENCE FOUNDATION, $1,199,970, "National Center for Geographic Information and Analysis", 1/01/96-12/31/97, PI: Goodchild.

NATIONAL SCIENCE FOUNDATION, $8,245,257, "National Center for Ecological Analysis and Synthesis, 5/1/96-4/30/00, PI: Murdoch, Co-PI: Goodchild.

OFFICE OF RESEARCH AND DEVELOPMENT, $209,677, "Heterogeneous Geographic Databases: Similarity Assessments, Year 2", 5/1/96-4/30/97, PI: Egenhofer.

OFFICE OF RESEARCH AND DEVELOPMENT, $79,694, "Image-Query-by-Sketch", 7/1/96-6/30/97, PI: Egenhofer, Co-PI: Agouris.

OFFICE OF SCIENCE AND TECHNOLOGY (TECHNOLOGY FORESIGHT PROGRAMME), UK, £1,100,000 (Industrial Match £ 2,200,000), "A Virtual Reality Centre for the Built Environment", 10/1/96-9/30/99, PI's: J.M. Batty, A. Penn (Project Directors), Co-PI's: P.J. Densham, D.P. Chapman, B. Hillier, R. Mackett, M. Slater, G. Winch.

UNIVERSITY OF CALIFORNIA, DAVIS, $38,880, "Multiple Endmember Mixture Analysis of Chaparral Using AVIRIS", 7/01/96-3/31/97, PI: Roberts.

UNIVERSITY OF CALIFORNIA, DAVIS, $36,000, "Coupling Ecophysiological Models with Remote Sensing Observations", 7/1/96-06/30/98, PI: Roberts.

UNIVERSITY OF CALIFORNIA, SANTA BARBARA, INSTRUCTIONAL DEVELOPMENT OFFICE, $12,000, "Mastering the Technical Issues of GIS (A Problem Solving Approach using ARC/INFO), 7/1/96-6/30/97, PI's: Goodchild, Kemp, Sutton.

US FOREST SERVICE, $22,500, "Regional Ecosystems and Land Management Decision Support System", 6/15/96-1/15/97, PI: Church.

DEPARTMENT OF TRANSPORTATION, $59,007, "Dwight D. Eisenhower Fellowship Program - Graduate Fellowship", 8/01/96-7/31/97, PI: Cova, Co-PI: Church.

US FOREST SERVICE, $50,000, "Extending Functionality on the Regional Ecosystem and Land Management Decision Support System", 9/03/96-9/30/97, PI: Church.

B. Equipment and Software Acquisitions

Maine

Power Macintosh 7600/120 and peripherals
Macintosh powerbook 190cs/66, 8/500
APS SCSI Drive (2)
Apple MessagePad 130
Color Quickcam
Videophone
Sportster 28.8 V.34 fax/modem
HP Laserjet 4M+ printer
Macromedia Director 5.0 for windows
Hypercard 2.3
Roaster Developer Release 1
Sonar Bookends version 4 for Mac
Newton Toolkit 1.6
ACT for Newton
Appgen
Newtpaint

Buffalo

2 Dell 5166 Computers
1 Dell 5100 Computer
3 SUN SPARCstation 5 workstations (Upgrade of 2 SUN IPX machines, and 1SPARCstation 1) and 1 16 MB SIMM for SUN Server
1 35 mm Desktop Film Scanner

Hewlett Packard Color Scanner

Santa Barbara

2 Intel Pentium Computers
2 21” Monitors
1 Pentium Powerbook
Sharp Copier

APPENDIX 1 - PUBLICATIONS

A. Articles published or formally accepted in refereed journals

Agouris, P. and T. Schenk (1996) Automated aerotriangulation using multiple image multipoint matching. *Photogrammetric Engineering and Remote Sensing* 62(6): 703-710.

Anas, A. and I. Kim (1996) General equilibrium models of polycentric urban land use with endogenous congestion and job agglomeration. *Journal of Urban Economics* 40(2): 232-256.

Armstrong, M.P. and R.J. Marciano (1996) Local interpolation using a distributed parallel supercomputer. *International Journal of Geographical Information Systems* 10(6): 713-729.

Armstrong, M.P. and R.J. Marciano (in press) Massively parallel strategies for local spatial interpolation *Computers and Geosciences.*

Batty, J.M. and P.J. Densham (1996) Decision support, GIS, and urban planning. *Systema Terra* 5(1): 72-76.

Batty, M. and Y. Xie (1996) Preliminary evidence for a theory of the fractal city. *Environment and Planning A* 28: 1745-1762.

Beard, M.K. and V. Sharma (in press) Multidimensional ranking in digital spatial libraries. *International Journal of Digital Libraries.*

Bian, L. and E. West (1997) Modeling elk calving habitat in a prairie environment with statistics. *Photogrammetric Engineering and Remote Sensing* 63(2): 161-167.

Bruns, T. and M. Egenhofer (in press) User interfaces for map algebra. *Journal of the Urban and Regional Information Systems Association*.

Buttenfield, B.P. (in press) Review of MacEachren, A.M., How Maps Work. *Environment and Planning B.*

Buttenfield, B.P. (1996) Review of MacEachren, A.M., Some Truth With Maps; A Primer on Symbolisation and Design. *International Journal of Geographical Information Systems* 10(5): 661-662.

Chakraborty, J. and M.P. Armstrong (1995) Using geographic plume analysis to assess community vulnerability to hazardous accidents. *Computers, Environment and Urban Systems* 19(5-6): 341-356.

Church, R.L., D.M. Stoms, and F.W. Davis (1996) Reserve selection as a maximal covering location problem. *Biological Conservation* 76(2): 105-112.

Clarke, K.C. (1996) Review of Waugh and Healey, Advances in GIS Research. *Cartography and Geographic Information Systems* 23(2): 100-101.

Cole, S. (1995) A spreadsheet approach to GIS. *Environment and Planning B* 22(2): 131-148.

Cole, S. (1995) Contending voices: futures, culture and development. *Futures* 27(4): 473-481.

Cole, S. (1995) Lifelines and livelihood: a social accounting matrix approach to calamity preparedness. *Journal of Contingencies and Crisis Management* 3(4).

Cole, S. (1995) Urban planning and planning support systems planning support systems, land use, transport, and the environment, urban conservation, and cross-national labour migration. *Regional Development Dialogue* 16(1).

Cole, S. (1996) Futures free fall: a modeler's tale. *Futures* 28(6-7): 539-542.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hamilton, S. Naeem, K. Limburg, J. Paruelo, R.V. O'Neill, R. Raskin, P. Sutton, and M. van den Belt (1997) The total value of the world's ecosystem services and natural capital. *Nature* 387(6630): 253-260.

Couclelis, H. (1997) From cellular automata to urban models: new principles for model development and implementation. *Environment and Planning B: Planning and Design* 24(2): 165-174.

Cova, T. and R. Church (in press) Spatial evacuation analysis: a GIS application frontier. *International Journal of Geographical Information Systems.*

Densham, P.J. and G. Rushton (1996) Providing spatial decision support for rural service facilities that require a minimum workload. *Environment and Planning B* 23(5): 553-574.

Dell, R.F., R. Batta, and M.H. Karwan (1996) The multiple vehicle TSP with time windows and equity constraints over a multiple day horizon. *Transportation Science* 30(2): 120-133.

Ding, Y.M. and P.J. Densham (1996) Spatial strategies for parallel spatial modeling. *International Journal of Geographical Information Systems* 10(6): 669-698.

Egenhofer, M. and A.R. Shariff (in press) Metric details for natural-language spatial relations. *ACM Transactions on Information Systems*.

Ehlschlaeger, C., A. Shortridge, and M.F. Goodchild (1997) Visualizing spatial data uncertainty using animation. *Computers and Geosciences* 23(4): 387-395.

Frank, S.M., M.F. Goodchild, H.J. Onsrud, and J.K. Pinto (1996) User requirements for framework geospatial data. *Journal of the Urban and Regional Information Systems Association* 8(2): 38-50.

Freundschuh, S.M. and M. Sharma (in press) Spatial image schemata, locative terms, and geographic spaces in children's narrative: fostering spatial skills in children. *Cartographica*.

Friedl, M.A., F.W. Davis, J. Michaelsen, and M. Moritz (1995) Scaling and uncertainty in the relationship between LAI and NDVI: an analysis using a scene simulation model and data from FIFE. *Remote Sensing of Environment* 54(3): 233-246.

Frohn R.C., K.C. McGwire, V.H. Dale, and J.E. Estes (1996) Using satellite remote sensing analysis to evaluate a socio-economic and ecological model of deforestation in Rondonia, Brazil. *International Journal of Remote Sensing* 17(16): 3233-3255.

Goodchild, M.F. and G.J. Hunter (1997) A simple positional accuracy measure for linear features. *International Journal of Geographical Information Systems* 11(3): 299-306.

Goodchild, M.F. and J. Proctor (1997) Scale in a digital geographic world. *Geographical and Environmental Modelling* 1(1): 5-24.

Hadzilacos, T. and N. Tryfona (1996) Logical data modelling for geographical applications. *International Journal of Geographical Information Systems* 10(2): 179-203.

Hunter, G.J. and M.F. Goodchild (1996) A new model for handling vector data uncertainty in geographic information systems. *Journal of the Urban and Regional Information Systems Association* 8(1): 51-57.

Hunter, G.J. and M.F. Goodchild (1996) Communicating uncertainty in spatial databases. *Transactions in GIS* 1(1): 13-24.

Hunter, G.J. and M.F. Goodchild (1997) Modeling the uncertainty in slope and aspect estimates derived from spatial databases. *Geographical Analysis* 29(1): 35-49.

Jin, H., R. Batta, and M.H. Karwan (1996) On the analysis of two new models for transporting hazardous materials *Operations Research* 44(5): 710-723.

Kemp, K.K. (1996) Fields as a framework for integrating GIS and environmental models. Part one: Representing spatial continuity. *Transactions in GIS* 1(3): 219-234.

Kemp, K.K. (1996) Fields as a framework for integrating GIS and environmental process models. Part two: Specifying field variables. *Transactions in GIS* 1(3): 235-246.

Kemp, K.K. and A.U. Frank (1996) Toward consensus on a European GIS curriculum: the international post-graduate course on GIS. *International Journal of Geographical Information Systems* 10(4): 477-497.

Krygier, J.B., C. Reeves, D. Dibiase, and J. Cupp (1997) Design, implementation, and evaluation of multimedia resources for geography and earth science education. *Journal of Geography in Higher Education* 21(1): 17-39.

Larsen, C.P.S. (1996) Fire and climate dynamics in the boreal forest of northern Alberta between 1850 and 1989. *The Holocene* 6: 449-456.

Larsen, C.P.S. (in press) Spatial and temporal variations in boreal forest fire frequency. *Journal of Biogeography*.

Leitner, M. and B.P. Buttenfield (1995) Multi-scale knowledge acquisition: inventory of European topographic maps. *Cartography and GIS* 22(3): 232-241.

Loaiciga, H.A. and R.B. Leipnik (1996) Stochastic renewal model of low-flow streamflow sequences. *Stochastic Hydrology and Hydraulics* 10(1): 65-85.

Loaiciga, H.A., R.B. Leipnik, P.F. Hudak, and M.A. Marino (1996) 1-, 2-, 3-dimensional effective conductivity of aquifers. *Mathematical Geology* 28(5): 563-584.

Lopez, X.R. (1996) Stimulating GIS innovation through the dissemination of geographic information. *Journal of the Urban and Regional Information Systems Association* 8(2): 24-37.

Malanson, G.P. and M.P. Armstrong (1996) Dispersal probability and forest diversity in a fragmented landscape. *Ecological Modelling* 87(1-3): 91-102.

Mark, D.M. and A.U. Frank (1996) Experiential and formal models of geographic space. *Environment and Planning B* 23(1): 3-24.

McGhie, R.G., J. Scepan, and J.E. Estes (1996) A comprehensive managed areas spatial database for the conterminous United States. *Photogrammetric Engineering and Remote Sensing* 62(11): 1303-1306.

Montello, D.R. (in press) Kartenverstehen: Die Sicht der Kognitionspsychologie [Understanding maps: The view from cognitive psychology]. *Seitschrift für Semiotik.*

Montello, D.R. and S.M. Freundschuh (1995) Sources of spatial knowledge and their implications for GIS: An introduction. *Geographical Systems* 2: 169-176.

Montello, D.R. (in press) Review of P. Roadway, Sensuous Geographies: Body, Sense, and Place. *Journal of Environmental Psychology*.

Murray, A.T. and R.L. Church (in press) Applying simulated annealing to location planning models. *Journal of Heuristics.*

Murray, A.T. and R.L. Church (in press) Using proximity restrictions for locating undesirable facilities. *Studies in Locational Analysis*, Special issue on Undesirable Facility Location.

Murray, A.T. and R.L. Church (1997) Solving the anti-covering problem using Lagrangian relaxation. C*omputers and Operations Research* 24(2): 127-140.

Murray, A.T. and R.L. Church (1996) Constructing and selecting adjacency constraints. *INFOR* 34(3): 232-248.

Murray, A.T. and R.L. Church (1996) Analyzing cliques for imposing adjacency restrictions in forest models. *Forest Science* 42: 166-175.

Onsrud, H.J., J. Johnson, and J. Winnecki (1996) GIS dissemination policy: two surveys and a suggested approach. *Journal of the Urban and Regional Information Systems Association* 8(2): 8-23.

Paiva, J. and M. Egenhofer (in press) Robust inference of the flow direction in river networks. *Algorithmica*.

Papadias, D. and Y. Theodoridis (1997) Spatial relations, minimum bounding rectangles, and spatial data structures. *International Journal of Geographical Information Systems* 11(2): 111-138.

Pickles, J. (1997) Tool or science? GIS, techno-science, and the theoretical turn. An invited response to Wright, Goodchild, and Proctor. .*Annals of the Association of American Geographers* 87(2): 363-372.

Razak, V. and S. Cole (1995) Anthropological perspectives on the future of culture and society - introduction. *Futures* 27(4): 375-384.

Reis, R. (1996) Geographic information systems and analysis: the future of the Public Trust Doctrine. *Albany Law Environmental Outlook* 2: 70-76.

Rogerson, P (1997) Inconsistencies in league standings. *Journal of Recreational Mathematics* 28: 1-4.

Rogerson, P. (in press) Some issues in global population modeling. *Futures*.

Rogerson, P. (in press) Surveillance systems for the development of spatial pattern. *Statistics in Medicine*.

Rogerson, P. (1997) Estimating the size of social networks. *Geographical Analysis* 29: 50-63.

Rogerson, P., J. Burr and G. Lin (in press) Changes in geographic proximity between parents and their adult children. *International Journal of Population Geography*.

Rogerson, P.A. (1996) Elderly Population Growth in the United States During the Late 1980s. *Growth and Change* 27: 75-95.

Rogerson, P. (1996) A generalization of Hewitt's test for seasonality. *International Journal of Epidemiology* 25(3): 644-648.

Rogerson, P.A. (in press) Review of A. Rogers, Multiregional Demography. *The Professional Geographer.*

Rokos, D.K.D. and M.P. Armstrong (1996) Using LINDA to compute spatial autocorrelation in parallel. *Computers and Geosciences* 22(4): 425-432.

Rugg, R., M. Egenhofer, and W. Kuhn (in press) Formalizing behavior of geographic feature types. *Geographical Systems.*

Smith, B. (1996) More things in heaven and earth. *Grazer Philosophische Studien* 50: 187-201.

Smith, B. (in press) Mereotopology: a theory of parts and boundaries. *Database and Knowledge Engineering.*

Smith, B. (in press) Boundaries: a Brentanian theory. *Brentano Studien* 8.

Smith, B. (in press) Review of S.S. Pollard and N.M. Martin, Closure Spaces and Logic. *History and Philosophy of Logic.*

Smith, B. (1997) Review of P.A. Burrough and A.U. Frank, Geographic Objects with Indeterminate Boundaries. *Dialectica.*

Smith, T.R., D. Andresen, L. Carver, R. Dolin, M.F. Goodchild, and others (1996) A digital library for geographically referenced materials. *Computer* 29(5): 54+ (corrected author list appears in 29(7): 14).

Sorensen, P. and R. Church (in press) A comparison of strategies for data storage reduction in location-allocation problems. *Geographical Systems.*

Springer, D.S., and H.A. Loaiciga (in press) Air permeability of porous materials under controlled laboratory conditions. *Water Resources Research.*

Takeyama, M. and H. Couclelis (1997) Map dynamics: integrating cellular automata and GIS through Geo-Algebra. *International Journal of Geographical Information Systems* 11(1): 73-91.

Thill, J.-C. (in press) Multi-outlet firms, competition and market segmentation strategies. *Regional Science and Urban Economics.*

Thill, J.-C. and J.L. Horowitz (in press) Travel-time constraints on destination choice sets. *Geographical Analysis.*

Tobler, W. (1997) The equidominance line: a new geopolitical concept. *Applied Geographical Studies* 1(1): 7-12.

Tobler, W., U. Deichmann, J. Gottsegen, and K. Maloy (in press) World population in a grid of spherical quadrilaterals. *International Journal of Population Geography.*

Tobler, W.R. (1995) Migration: Ravenstein, Thornthwaite, and beyond. *Urban Geography* 16(4): 327-343.

Tobler, W.R. (1997) Movement modeling on the sphere. *Geographical and Environmental Modelling* 1(1): 97-103.

Tobler, W.R. (1996) A graphical introduction to survey adjustment. *Cartographica* 32(1): 33-42.

Tryfona, N. and M.J. Egenhofer (in press) Consistency among parts and aggregates: a computational model. *Transactions in Geographical Information Systems.*

Wright, D.J., M.F. Goodchild, and J.D. Proctor (1997) Demystifying the persistent ambiguity of GIS as 'tool' versus 'science'. *Annals of the Association of American Geographers* 87(2): 346-362.

Zhan, F. and B.P. Buttenfield (in press) Multi-scale representations of digital cartographic lines. *Cartography and Geographic Information Systems.*

B. Books

Aldenderfer, M. and H.D.G. Maschner, editors (1996) *Anthropology, Space, and Geographic Information Systems*. New York: Oxford University Press.

Clarke, K. C. (1997) *Getting Started With Geographic Information Systems.* Upper Saddle River, NJ: Prentice Hall.

Egenhofer, M. and R. Golledge, editors (in press) *Spatial and Temporal Reasoning in Geographic Information Systems.* New York: Oxford University Press.

Longley, P. and M. Batty, editors (1996) *Spatial Analysis: Modelling in a GIS Environment.* Cambridge: GeoInformation International.

Quattrochi, D.A. and M.F. Goodchild, editors (1997) *Scale in Remote Sensing and GIS*. Boca Raton: Lewis Publishers.

Star, J.L., J.E. Estes, and K.C. McGwire (editors) *Integration of Geographic Information Systems and Remote Sensing*. Cambridge: Cambridge University Press.

C. Articles in Refereed Conference Proceedings

Armstrong, M.P. and P.J. Densham (1997) Toward a network map algebra. *Proceedings of the Thirteenth International Symposium on Automated Cartography (Auto-Carto 13).* Bethesda, MD: American Congress on Surveying and Mapping: 1-10.

Beard, M.K. (in press) Managing metadata for global scale coverages. *Proceedings Auto-Carto 13, Seattle, WA, April 1997*: 404-415.

Bennett, D.A., G. Wade, and M.P. Armstrong (in press) Linking geographic models with 2D genetic algorithms to explore semi-structured spatial problems *In press, Proceedings of the Thirteenth International Symposium on Automated Cartography (Auto-Carto 13).* Bethesda, MD: American Congress on Surveying and Mapping: 234-243.

Bruns, H.T. and M.J. Egenhofer (1996) Similarity of Spatial Scenes. *Proceedings, Seventh International Symposium on Spatial Data Handling (SDH '96), Delft, The Netherlands*: 4A.31-4A.42.

Egenhofer, M. (1996) Spatial-query-by-sketch. In M. Burnett and W. Citrin (editors), *VL'96: IEEE Symposium on Visual Languages, Boulder, CO*: 60-67.

Egenhofer, M.J. (1996) Multi-modal spatial querying. *Proceedings, Seventh International Symposium on Spatial Data Handling (SDH '96), Delft, The Netherlands*: 12B.1-12B.15.

Florence, J., K. Hornsby, and M.J. Egenhofer (1996) The GIS WallBoard: interactions with spatial information on large-scale displays. *Proceedings, Seventh International Symposium on Spatial Data Handling (SDH '96), Delft, The Netherlands*: 8A.1-8A.15.

Fohl, P., K.M. Curtin, M.F. Goodchild, and R.L. Church (1996) A non-planar, lane-based navigable data model for ITS. In M.J. Kraak and M. Molenaar, editors, *Proceedings, Seventh International Symposium on Spatial Data Handling, Delft, August 12-16*: 7B.17-7B.29.

Kemp, K.K. (1997) Integrating traditional spatial models of the environment with GIS. *Proceedings, AutoCarto 13, Seattle, April*: 23-32.

Leitner, M. and B.P. Buttenfield (1997) Cartographic guidelines on the visualization of attribute accuracy. *Proceedings, AutoCarto 13, Seattle, April*: 184-194.

Papadias, D., M. Egenhofer, and J. Sharma (1996) Hierarchical reasoning about direction relations. In S. Shekhar and P. Bergougnoux (editors) *4th ACM Workshop on Advances in Geographic Information Systems, Rockville, MD*: 107-114.

Pazner, M.I. and M.J. Lafreniere (1997) GIS icon maps. *Proceedings, AutoCarto 13, Seattle, April*: 126-135.

Raskin, R., C. Funk, and C. Willmott (1997) Interpolation over large distances using Spherekit. *Proceedings, AutoCarto 13, Seattle, April*: 419-428.

Schroeder, P. (1997) A public participation approach to charting information spaces. *Proceedings, AutoCarto 13, Seattle, April*: 244-253.

Skupin, A. and B.P. Buttenfield (1997) Spatial metaphors for visualizing information spaces. *Proceedings, AutoCarto 13, Seattle, April*: 116-125.

Sutton, P. (1997) A comparison of the low-gain and high-gain DMSP nighttime satellite imagery products for use in modeling population density over the continental United States. *Proceedings, AutoCarto 13, Seattle, April 1997*.

Tobler, W. Demography in global change studies. *Proceedings, AutoCarto 13, Seattle, April 1997.*

Tryfona, N. and M.J. Egenhofer (1996) Multi-resolution spatial databases: consistency among networks. *Proceedings, Sixth International Workshop on Foundations of Models and Languages for Data and Objects, Schloss Dagstuhl, Germany*: 119-132.

Tryfona N, and J. Sharma (1996) Modeling issues to support interoperability in geographic databases. *Proceedings, Eighth International Conference on Advanced Information Systems Engineering (CAISE 1996)*: 210-221.

Tryfona, N., N. Soulakellis, and P. Delladetsimas (1996) Designing a decision support tool for an emergency management application. *First International Conference on Environmental, Regional and Urban Planning, Samos, Greece*: 113-122.

Tsou, M.H. and B.P Buttenfield (1996) A direct manipulation interface for geographical information processing. *Proceedings 6th International Symposium on Spatial Data Handling, Delft, The Netherlands, August 1996*: 13B.37-13B.47.

Van Zuyle, P. Improving moving maps: a system for feature selection based on a new cognitive model. *Proceedings, Auto-Carto 13, Seattle, April 1997.*

D. Articles in other outlets

Agouris, P. and A. Stefanidis (1996) Integration of photogrammetric and geographic databases. *ISPRS XVIII Congress, Vienna, Austria* 31(B4): 24-29.

Agouris, P. and A. Stefanidis (1996) Automated extraction of man-made objects from digital imagery. *ASPRS/ACSM 1996 Conference, Baltimore, MD* 1: 179-187.

Armstrong, M.P. and R.J. Marciano (1996) Distributed parallelism: impacts on GIS and collaborative spatial decision-making *Proceedings of GIS/LIS 96.* Bethesda, MD: American Congress on Surveying and Mapping: 527-539.

Beard, K. (1997) Represention of data quality. In M. Craglia and H. Couclelis (editors) *Geographic Information Research: Bridging the Atlantic*. London: Taylor and Francis: 280-294.

Beard, M.K. (1996) A structure for organizing metadata collection. *Proceedings, 3rd International Conference/Workshop on Integrating GIS and Environmental Modeling, Sante Fe, NM* (CD and http://www.ncgia.ucsb.edu).

Beard, M.K and T.R. Smith (in press) A framework for meta-information in digital libraries. In A. Sheth and W. Klaus (editors) *Managing Multimedia Data: Using Metadata to Integrate and Apply Digital Data*.

Beard, M.K. and B. Buttenfield (in press) Graphical detection and evaluation of uncertainty. In P.A. Longley, M.F. Goodchild, D.J. Maguire, and D.W. Rhind (editors) *Geographic Information Systems: Principles, Techniques, Management and Applications*. Cambridge: GeoInformation International.

Bennett, D.A., M.P. Armstrong and G.A. Wade (1996) Agent mediated consensus-building for environmental problems: a genetic algorithm approach. *Proceedings of the Third International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling* (CD and http://www.ncgia.ucsb.edu).

Bian, L. (1997) Multiscale nature of spatial data in scaling up environmental models. In M.F. Goodchild and D.A. Quatttrochi (editors) *Scale in Remote Sensing and GIS*. Boca Raton, FL: Lewis Publishers: 13-26.

Bian, L., H. Sun, C.F. Blodgett, S.L. Egbert, W. Li, L. Ran, A.D. Koussis (1996) An integrated interface system to couple the SWAT model and ARC/INFO. *Proceedings, Third International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling* (CD and http://www.ncgia.ucsb.edu).

Buttenfield, B.P. (1996) GIS and digital libraries: issues of size and scalability. In L.C. Smith and M. Gluck (editors) *GIS and Libraries: Patrons, Spatial Data and Services.* Champaign-Urbana: Graduate School of Library and Information Science: 69-80.

Buttenfield, B.P. (1996) Scientific visualization for environmental modeling: interactive and proactive graphics. In M.F. Goodchild, L.T. Steyaert, B.O. Parks, C. Johnston, D. Maidment, M. Crane and S. Glendenning (editors) *GIS and Environmental Modeling: Progress and Research Issues*. Fort Collins, CO: GIS World Books: 463-469.

Buttenfield, B.P (in press) Delivering maps to the information society: a digital library for cartographic data. Proceedings, 17th Conference of the International Cartographic Association, June 1997, Gaevle, Sweden.

Buttenfield, B.P. and M.H. Tsou (in press) Encapsulated operators for processing geographic information. *Proceedings, Second Workshop on Progress in Automated Map Generalization, Gaevle, Sweden, 19-21 June.*

Buttenfield, B.P. and M.F. Goodchild (1996) The Alexandria Digital Library project: distributed library services for spatially referenced data. *Proceedings, GIS/LIS, Denver, Colorado, November 1996*: 76-84.

Buttenfield, B.P. and M.P. Kumler (1996 Tools for browsing environmental data: the Alexandria Digital Library interface. *Proceedings, Third International Conference/Workshop on Integrating GIS and Environmental Modeling, Santa Fe, NM, January*. (CD and http://www.ncgia.ucsb.edu).

Chakraborty, J. and M.P. Armstrong (1995) A composite plume approach to assessing community vulnerability to hazardous material accidents. *Proceedings of the Annual Conference of the Urban and Regional Information Systems Association.* Washington, DC: Urban and Regional Information Systems Association: 249-260.

Chakraborty, J. and M.P. Armstrong (1996) A comparison of GIS-based approaches to environmental equity analysis. *Proceedings, GIS/LIS '96, Denver, Colorado, November*: 839-852.

Church, R., D. Stoms, F. Davis, and B.J. Okin (1996) Planning management activities to protect biodiversity with a GIS and an integrated optimization model. *Proceedings, Third International Conference/Workshop on Integrating GIS and Environmental Modeling, Santa Fe, NM, January 21-25, 1996*. Santa Barbara, CA: National Center for Geographic Information and Analysis (CD and http://www.ncgia.ucsb.edu).

Church, R.L. and C. ReVelle (in press) Fundamentals of location and layout problems. In H.A. Eiselt and C.L. Sandblom (editors) *Operations Research*.

Clarke, K.C. (1996) The future of GIS. *Proceeding, Information Systems for Public Health Organizations Convference, CDC, Atlanta, 1996.*

Coan, M. and M.J. Egenhofer (1996) The ontology of land boundaries under natural change: erosion and accretion of sandy shoals in Nantucket Sound. *ASPRS/ACSM 1996 Conference, Baltimore, MD* 3: 306-313.

Cole, S. (1995) The socio-economic and inter-regional impacts of an earthquake-decision support for calamity preparedness in the United States. *Proceedings, 42nd North American Meeting of the Regional Science Association International, Cincinnati, Ohio, November.*

Cole, S. (1996) A GIS-based many-region disaster preparedness model for the United States. *Proceedings, Third International Conference/Workshop on Integrating GIS and Environmental Modeling, January 21-25, Santa Fe, New Mexico* (CD and http://www.ncgia.ucsb.edu)

Cole, S. (1996) Input-output forecasts and empirical testing the economic impact of the Ravenscraig steelworks shutdown. *Proceedings, Nineteenth Annual Meeting, Northeast United States Region of the Regional Science Association Internationat, Session on Regional Development in Scotland, April 26-27, Binghamton University*.

Cole, S. (1995) The future belongs to anthropology. *Anthropology Newsletter* 36(5).

Cole, S. and V. Razak (1993) Transforming time bombs into time share - the futures of cultural complexity. *Proceedings, the XIII World Conference of the World Futures Studies Federation: Coherence and Chaos in our Uncommon Futures - Visions, Means, Actions, August 23-27, Turku, Finland.*

Cope, M. (in press) Responsibility, regulation and retrenchment: the end of welfare? In L. Staeheli, J. Kodras, and C. Flint (editors) *Changing American Governance: Implications for a Diverse Society.* Sage Urban Affairs Annual Review.

Couclelis, H. (in press) Spatial information technologies and societal problems. In M. Craglia, and H. Onsrud (editors) *Proceedings of the 1996 International Young Scholars Summer Institute in Geographic Information*. London: Taylor and Francis.

Couclelis H. (1996) Verbal directions for way-finding: space, cognition, and language. In J. Portugali (editor) *The Construction of Cognitive Maps.* Amsterdam: Kluwer Academic Publishers: 133-153.

Couclelis H. (1996) Towards an operational typology of geographic entities with ill-defined boundaries. In P. Burrough and A. Frank (editors) *Geographic Objects with Indeterminate Boundaries*. London: Taylor and Francis: 45-55.

Couclelis H. (in press) GIS without computers: building geographic information science from the ground up. In Z. Kemp and P. Fisher (editors) *Innovations in GIS: 4*. London: Taylor and Francis.

Couclelis, H. (in press) Space, time, geography. In P. Longley, M.F. Goodchild, D. Maguire, and D. Rhind (editors) *Geographic Information Systems: Principles, Techniques, Management and Applications.* Cambridge: GeoInformation International.

Couclelis, H., editor (1996) *Spatial Technologies, Geographic Information, and the City. Report of the Baltimore Research Conference*. Technical Report 96-10. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Cramer, B.E. and M.P. Armstrong (1996) A distributed parallel approach to computation of a spatial statistic. *Proceedings of GIS/LIS '96.* Bethesda, MD: American Congress on Surveying and Mapping: 280-294.

Densham, P.J. (1996) Visual interactive locational analysis. In P. Longley and M. Batty (editors) *Spatial Analysis: Modelling in a GIS environment*. Cambridge: GeoInformation International: 185-206.

Densham, P.J. and M.P. Armstrong (1996) Spatial analysis. In R.G. Healey, S. Dowers, B.M. Gittings, and M.J. Mineter (editors) *Parallel Processing Algorithms for GIS.* London: Taylor and Francis.

Eagles, D.M. and H.W. Calkins (1996) *Geographic Information Analysis and Human Capital Research: A report to the National Science Foundation and the Department of Housing and Urban Development.* Buffalo, NY: U.B. Publications.

Egenhofer, M. and W. Kuhn (in press) Query languages for GIS. In P. Longley, M. Goodchild, D. Maguire, and D. Rhind (editors) *Geographical Information Systems: Principles, Techniques, Management and Applications*. Cambridge: GeoInformation International.

English, D. and J.-C. Thill (1996) Estimating recreation travel through spatial units from limited survey data. Research Note SRS-2. U.S. Department of Agriculture, Forest Service, Southern Research Station.

Estes, J.E. (1996) A perspective on trends in conservation, GAP, and a vision for the future of biodiversity managed areas. In M. Scott, T. Tear, and F. Davis (editors) *Proceedings, GAP Analysis: A Landscape Approach to Biodiversity Planning*. Falls Church, VA: American Society of Photogrammetry and Remote Sensing: 299-306.

Estes, J.E., S. Morain, T. Foresman, and J. Scepan (1996) Image formation and raster characteristics. In *Raster Imagery: Geographic Information Systems*. Santa Fe, NM: Word Press: 1-27.

Felkner, J. (1996) An analysis of international data transfer. *International Society of Photogrammetry and Remote Sensing (ISPRS) Conference Proceedings , July1996, Vienna.*

Florence, J. and M.J. Egenhofer (1996) Distribution of topological relations in geographic datasets. *ASPRS/ACSM 1996 Conference, Baltimore, MD* 3: 314-324.

Fogel, D.N. (1996) Image rectification with radial basis functions: application to RS/GIS data integration. *Proceedings, Third International Conference/Workshop on Integrating GIS and Environmental Modeling, Santa Fe, NM, January 21-25, 1996*. Santa Barbara, CA: National Center for Geographic Information and Analysis (CD and http://www.ncgia.ucsb.edu).

Foresman, T.W., T. Serpi, J.E. Estes, and K. Kline (1996) NCGIA curriculum in remote sensing. *Proceedings, GIS/LIS '96, Denver, Colorado, November*: 362.

Goodchild, M.F. (1995) Attribute accuracy. In S.C. Guptill and J.L. Morrison (editors) *Elements of Spatial Data Quality*. New York: Elsevier: 59-80.

Goodchild, M.F. (1995) GIS state of the art. *First National Conference on the Educational Applications of Geographic Information Systems (EdGIS).* Washington, DC: National Science Foundation: 35-37.

Goodchild, M.F. (1995) Spatial databases for global environmental issues. In S. Murai (editor) *Toward Global Planning of Sustainable Use of the Earth*. Proceedings of the Eighth TOYOTA Conference, Mikkabi, November 8-11, 1994. Amsterdam: Elsevier: 43-58.

Goodchild, M.F. (1996) Generalization, uncertainty, and error modeling. *Proceedings, GIS/LIS '96, Denver, Colorado, November*: 765-774.

Goodchild, M.F. (1996) Directions in GIS. *Proceedings, Third International Conference/Workshop on Integrating GIS and Environmental Modeling, Santa Fe, NM, January 21-25, 1996*. Santa Barbara, CA: National Center for Geographic Information and Analysis (CD and http://www.ncgia.ucsb.edu).

Goodchild, M.F. (1996) Geographic information systems and spatial analysis in the social sciences. In M. Aldenderfer and H.D.G. Maschner (editors) *Anthropology, Space, and Geographic Information Systems*. New York: Oxford University Press: 241-250.

Goodchild, M.F. (1996) The application of advanced information technology in assessing environmental impacts. In D.L. Corwin and K. Loague (editors) *Applications of GIS to the Modeling of Non-Point Source Pollutants in the Vadose Zone*. SSSA Special Publication No. 48. Madison, WI: SSSA: 1-18.

Goodchild, M.F. (1997) Geographic information systems. In S. Hanson (editor) *Ten Geographic Ideas that Changed the World*. New Brunswick, NJ: Rutgers University Press: 60-86.

Goodchild, M.F. (1997) Postscript: new directions for GIS research. In M. Craglia and H. Couclelis (editors) *Geographic Information Research: Bridging the Atlantic*. London: Taylor and Francis: 588-596.

Goodchild, M.F. and D.A. Quattrochi (1997) Introduction: scale, multiscaling, remote sensing, and GIS. In D.A. Quattrochi and M.F. Goodchild (editors) *Scale in Remote Sensing and GIS*. Bocan Raton: Lewis Publishers: 1-13.

Gottsegen, J.M. and A.T. Murray (1996) Analyzing the relationships of spatial structure in aggregated data. *Proceedings, GIS/LIS '96, Denver, Colorado, November*: 457-466.

Gould, M.D., J. Nunes, D. Comas, M.J. Egenhofer, S.M. Freundschuh and D.M. Mark (1996) Formalizing informal geographic information: cross-cultural human subjects testing. *Proceedings, Joint European Conference on GIS, Barcelona* 1: 285-294.

Hernon, P. and X.R. Lopez (1996) Geographic information systems. In P. Hernon, C.R. McClure, and H.C. Relyea (editors) *Federal Information Policies in the 1990's: Views and Perspectives*. Norwood: Ablex Publishing: 233-257.

Jankowski, P. and M. Stasik (1996) Architecture for space and time distributed collaborative decision making. *Proceedings, GIS/LIS '96, Denver, Colorado, November*: 516-526.

Johnson, T., J. Dozier, J. Michaelsen, and P. Fohl (1996) Climate change in Sierra Nevada snowpack. *Proceedings of the International Snow Science Workshop, Banff, Alberta, Canada, October 7-10, 1996*.

Kemp, K.K. (1996) GIS and geography education. In H. Chamussy, R. P. Bradshaw, and M. Antrop (editors) *Intelligent Tutorial Systems in Geography*. Springer-Verlag.

Kemp, K.K. (1996) Managing spatial continuity for integrating environmental models with GIS. In M. F. Goodchild, L. T. Stayaert, B. O. Parks, C. Johnston, D. Maidment, M. Crane, and S. Glendinning (editors) *GIS and Environmental Modeling: Progress and Research Issues*. Fort Collins, CO: GIS World Books: 339-343.

Kemp, K.K. (1996) The original NCGIA core curriculum in GIS. *Proceedings, GIS/LIS '96, Denver, Colorado, November*: 361.

Kemp, K.K. (1996) Easing environmental models into GIS. *Proceedings, Third International Conference/Workshop on Integrating GIS and Environmental Modeling, Santa Fe, NM, January 21-25, 1996*. Santa Barbara, CA: National Center for Geographic Information and Analysis (CD and http://www.ncgia.ucsb.edu).

Kemp, K.K. and M.F. Goodchild (1996) The new on-line core curriculum in geographic information science. *Proceedings, GIS/LIS '96, Denver, Colorado, Novembe*: 363.

Krygier, J.B (1996) Geography and cartographic design. In C. Wood and C. Keller (editors) *Cartographic Design: Theoretical and Practical Perspectives.* New York: Wiley.

Leitner, M. and B.P. Buttenfield (1996) The impact of data quality displays on spatial decision support. *Proceedings, GIS/LIS '96, Denver, Colorado, November*: 882-894.

Lemberg, D.S. and R.L. Church (1996) Feasible alternatives generation in collaborative spatial decision making. *Proceedings, GIS/LIS '96, Denver, Colorado, November*: 501-515.

Lopez, X.R. (1996) A comparative survey of national information policies and their impact on access to spatial datasets. *Proceedings, GIS/LIS '96, Denver, Colorado, November*: 642-655.

Lopez, X.R. (1997) Spatial data as a testbed for national information policy. In M. Craglia and H. Couclelis (editors) *Geographic Information Research: Bridging the Atlantic*. London: Taylor and Francis: 37-58.

Lutz, M., N. Marth, H. Onsrud, J. Robinson, and K. Zeiner (1996) Spatial Odyssey: the wired world of GIS conference proceedings. *ASPRS/ACSM 1996 Conference, Baltimore, MD* 3: 330-335.

Macklin, S.J. (1996) Spatial Horizons: new directions for secondary education. *ASPRS/ACSM 1996 Conference, Baltimore, MD* 3: 325-329.

Mark, D.M. (1997) Cognitive perspectives on spatial and spatio-temporal reasoning. In M. Craglia and H. Couclelis (editors) *Geographic Information Research: Bridging the Atlantic*. London: Taylor and Francis: 308-319.

Mark, D.M. (in press) Spatial representation: a cognitive view. In P. Longley, M. Goodchild, D. Maguire, and D. Rhind (editors) *Geographical Information Systems: Principles, Techniques, Management, and Applications.* Cambridge: GeoInformation International.

Mark, D.M. and M.J. Egenhofer (1996) Common-sense geography: foundations for intuitive geographic information systems. *Proceedings, GIS/LIS '96*: 935-941.

McGwire, K. and M.F. Goodchild (1997) Accuracy. In J.L. Star, J.E. Estes, and K.C. McGwire (editors) *Integration of Geographic Information Systems and Remote Sensing*. Cambridge: Cambridge University Press: 110-133.

McMaster, R.B. and B.P. Buttenfield (1997) Formalizing cartographic knowledge. In M. Craglia and H. Couclelis (editors) *Geographic Information Research: Bridging the Atlantic.* London: Taylor and Francis: 205-223.

Messina, P., P. Stoffer and K.C. Clarke (1997) Mapping Death Valley's rolling stones. *GPS World* (April).

Montello, D.R. and A.U. Frank (1996) Modeling directional knowledge and reasoning in environmental space: testing qualitative metrics. In J. Portugali (editor) *The Construction of Cognitive Maps.* Dordrecht: Kluwer Academic: 321-344.

Onsrud, H.J. (1996) Government data dissemination policy: meeting both open access and cost recovery objectives. *ASPRS/ACSM 1996 Conference, Baltimore, MD* 1: 343.

Pazner, M.I. (1996) A student-friendly system for learning raster GIS. *Proceedings, GIS/LIS '96, Denver, Colorado, November*: 663-674.

Petitot, J. and B. Smith (1996) Physics and the phenomenal world. In R. Poli and P. M. Simons (editors), *Formal Ontology*. Dordrecht/Boston/Lancaster: Kluwer.

Pickles, J. (in press) Arguments, debates, and dialogues: the GIS-social theory debate and the concern for alternatives. In P. Longley, M. Goodchild, D. Maguire, and D. Rhind (editors) *Geographical*

Information Systems: Principles, Techniques, Management, and Applications. Cambridge: GeoInformation International.

Pinto, J. and H. Onsrud (1997) Human and organisational factors in GIS implementation. In M. Craglia and H. Couclelis (editors) *Geographic Information Research: Bridging the Atlantic*. London: Taylor and Francis: 129-145.

Ramlal, B. and K. Beard (1996) An alternate paradigm for representing soils data and data quality information. *Proceedings, 3rd International Conference/Workshop on Integrating GIS and Environmental Modeling, Sante Fe, NM* (CD and http://www.ncgia.ucsb.edu).

Rogerson, P. (in press) A spatial version of the Chi-square goodness-of-fit test and its application to tests for spatial clustering. In D. Griffith (editor) *Advances in Spatial Modeling and Methodology*.

Rogerson, P.A. (1996) What percentage of Americans ever born are alive today? *American Demographics* March.

Ruggles, A. and R. Church (1996) Spatial allocation in archaeology: an opportunity for re-evaluation. In H.D.G. Mascher (editor) *New Methods, Old Problems: Geographic Information Systems in Modern Archaeological Research*. Southern Illinois University Press.

Schroeder, P. (in press) Organizing advocacy for network services in Maine: political background of a successful initiative. *Proceedings of INET' 96: Internet and Social Transformation, Montreal, June 25-28, 1996.*

Skupin, A. and B.P. Buttenfield (1996) Spatial metaphors for visualizing very large data archives. *Proceedings, GIS/LIS '96, Denver, Colorado, November*: 607-617.

Smith, B. (in press) Boundaries. In L.H. Hahn (editor) *The Philosophy of Roderick Chisholm.* Chicago and LaSalle: Open Court.

Smith, B. (1997) The cognitive geometry of war. In P. Koller and K. Puhl (editors) *Problems of Contemporary Political Philosophy*. Vienna: Holder-Pichler-Tempsky.

Smith, B. and L. Zaibert (1996) Prolegomena to a metaphysics of real estate. In R. Caseti (editor) *Shadows and Socio-Economic Units: Foundations of Formal Geography*. Vienna: Department of Geoinformation, Technical University of Vienna: 151-155.

Smith, B. (1996) Truth and the visual field. In J. Petitot and J.-M. Roy (editors) *Phenomenology and Cognitive Science*. Stanford: Stanford University Press.

Sorensen, P. and R. Church (1996) Integrating normative location models into GIS: problems and prospects with the p-median model. In P. Longley and M. Batty (editors) *Spatial Analysis: Modelling in a GIS Environment*. Cambridge: GeoInformation International.

Stefanidis, A. and P. Agouris (1996) Integrated photogeographic databases. *ASPRS/ACSM 1996 Conference, Baltimore, MD* 3: 32-40.

Stefanidis, A. and P. Agouris (1996) Scale difference considerations in conjugate feature matching. *ISPRS XVIII Congress, Vienna, Austria* 31(B3): 8-13.

Sugita, S., G.M. MacDonald, and C.P.S. Larsen (1997) Reconstruction of fire disturbance and forest succession from fossil pollen in lake sediments: potential and limitations. In J.S. Clark (editor) *Sediment Rrecords of Biomass Burning and Global Change.* New York: Springer-Verlag.

Sutton, P. (1997) Light up your nation: an ArcView based education module exploring nighttime satellite imagery and GIS. *Proceedings, 1997 ACSM/ASPRS Annual Convention, Seattle.*

Sutton, P. (1997) Using GIS to model population density: an evaluation of the combined effectiveness of using Sir-C Radar, DMSP nighttime satellite imagery, and the AVHRR greeness index for measuring human population density. *Proceedings, University Consortium for Geographic Information Science Annual Assembly, Bar Harbor, Maine, June 1997* (http://www.ucgis.org).

Tobler, W. (1996) Converting administrative unit data to a continuous field on a sphere. *Proceedings, Third International Conference/Workshop on Integrating GIS and Environmental Modeling, Santa Fe, NM, January 21-25, 1996.* Santa Barbara, CA: National Center for Geographic Information and Analysis (CD and http://www.ncgia.ucsb.edu).

Tobler, W. (1997) Vizualizing the impact of transportation on spatial relations. *Proceedings, Western Regional Science Association Conference, Kona, February 1997*.

Woldenberg, M.J. (1997) James Keill (1708) and the morphometry of the microcosm: geometric progression on laws in arterial trees. In David R. Stoddard (editor) *Form and Process in Geomorphology*. London: Routledge.

Xia, Zong-guo and K.C. Clarke (1996) Approaches to scaling of spatial data in the geosciences. In D.A. Quattrochi and M.F. Goodchild (editors) *Scale in Remote Sensing and GIS.* Boca Raton: Lewis Publishers.

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

Bansal, A., P. Zhao and R. Batta. Aggregation error in single-facility location problems. *Computers and Operations Research*

Buttenfield, B.P. and R. Weibel. Vizualizing the uncertainty of GIS data. *Transactions in GIS.*

Chattin, L., R. Batta, and S.Y. Prasad. Maximizing expected coverage using state sensitive dispatch assignments. *Management Science*.

Church, R., D. Stoms, and F. Davis. Developing a multiobjective reserve selection model. *Biological Conservation*.

Densham, P.J., M.P. Armstrong, M.F. Goodchild, B. Ralston and G. Rushton. Perspectives on spatial decision support systems. *Environment and Planning B.*

Eagles, D.M. and R.K. Carty. The political ecology of local party organization: the case of Canada. *Political Geography*.

Hadzilacos, T. and N. Tryfona. Extending the Entity-Relationship model to capture semantics of spatial applications. *Eighth International Conference on Conceptual Modeling - ER '96.*

Jamil, M., R. Batta, and A. Baveja. The stochastic queue center problem. *Location Science.*

Jin, H. and R. Batta. Objectives derived from viewing Hazmat shipments as a sequence of independent Bernoulli trials. *Transportation Science*.

Jin, H. and R. Batta. Hazmat routing viewed as a probabilistic experiment *Transportation Science.*

Kemp, K.K. The NCGIA core curricula in GIS and remote sensing. *Transactions in GIS.*

Killion, M., L. Bian, and H. Milton. An analysis of bald eagle winter habitat in central Kansas. *Landscape Ecology*.

Krygier, J.B. Envisioning the American West. *Cartography and Geographic Information Systems* .

Krygier, J.B. Project Ketch: Project Plowshare in Pennsylvania. *Ecumene*.

Larsen, C.P.S. and G.M. MacDonald. An 840 year record of fire and vegetation in a boreal white spruce forest. *Ecology*.

Larsen, C.P.S., R. Pienitz, J.P. Smol, K.A. Moser, B.F. Cumming, J.M. Blais, G.M. MacDonald, and R.I. Hall. Relations between lake morphometry and the presence of laminated sediments: a re-examination of Larsen and MacDonald. *Quaternary Science Reviews.*

Leitner, M. and B.P. Buttenfield. Acquisition of cartographic knowledge by reverse engineering. *Cartography and Geographic Information Systems.*

Marciano, R.J. and M.P. Armstrong. On the use of parallel processing for interactive analysis of large GIS datasets: the effect of control point distribution on interpolation performance. *Communications of the Association for Computing Machinery*.

Moser, K.A., S.J. Taylor, C.P.S. Larsen, G.M. MacDonald, and J.P. Smol. A paleolimnological investigation of the response of a boreal lake in northern Alberta to the last 200 years of forest fires and climatic changes. *Journal of Paleolimnology*.

Murray, A. and R. Church. Facets for node packing. *European Journal of Operational Research.*

Reed, W.J., C.P.S. Larsen, E.A. Johnson, and G.M. MacDonald. Estimation of temporal variations in fire frequency from dendrochronological time-since-fire data. *Canadian Journal of Forest Research.*

Roberts, D., M. Gardner, R. Church, S. Ustin, G. Scheer, and R. Green. Mapping chaparral in the Santa Monica Mountains using multiple endmember spectral mixture models. *Remote Sensing of Environment*.

Tobler, W. Alternatives to Miller's projection. *Cartography and Geographical Information Systems.*

Tryfona, N., D. Pfoser, and T. Hadzilacos. Modeling behavior of geographic objects: an experience with object modeling technique. *Ninth International Conference on Advanced Information Systems and Engineering (CAiSE) Spain, 1997.*

Zhao, P. and R. Batta. Analysis of centroid aggregation for the Euclidean distance p-median problem. *European Journal of Operational Research.*

Zhao, P. and R. Batta. An aggregation approach to solving the network p-median problem with link demands. *Networks.*

APPENDIX 2 - PRESENTATIONS BY NCGIA PERSONNEL

January 15-26: Uwe Deichmann visited the United Nations Environment Programme/Global Resource Information Database (UNEP/GRID) in Geneva to work on the development of models for an Asian population database. A final database, documentation, and methods report was produced in March 1996, http://www.ncgia.ucsb.edu/~uwe/aspop . A fifty page review paper for the UNEP/CGIAR Initiative on the Use of GIS in Agricultural Research, titled "A Review of Spatial Population Database Design and Modeling", was completed.

January 21-25: NCGIA Buffalo participants in the Third International Conference/ Workshop on Integrating Geographic Information Systems and Environmental Modeling, Santa Fe, NM included: Ling Bian, "An integrated interface system to couple the SWAT model and ARC/INFO"; Sam Cole, "A GIS-Based Many-Region Disaster Preparedness Model for the United States"; Chris Larsen; and Laura Kracker; Marc Armstrong, University of Iowa, "Agent mediated consensus-building for environmental problems: A genetic algorithm approach" (with David Bennett). Kate Beard and Bheshem Ramlal attended from Maine. Beard presented "A Structure for Organizing Metadata Collection", and "An Alternate Paradigm for Representing Soils Data and Data Quality Information". From Santa Barbara, Michael Goodchild presented the keynote address "Directions in GIS". John E. Estes was the Session Chair for the EOSDIS Special Session, and also made a presentation entitled "EOS Potential User Model Development". Richard Church presented the paper "Planning Activities to Protect Biodiversity with a GIS and an Integrated Optimization Model" co-authored by D. Stoms, F. Davis, and B.J. Okin.

February: Michael Goodchild presented the keynote address "Directions in GIS" at the California GIS Conference 1996 in San Francisco.

February: Michael Goodchild made a presentation entitled "Geographic Information Science and Geography" at the University of Western Ontario, Department of Geography, and also at Michigan State University, Department of Geography.

February: Michael Goodchild presented "The Alexandria Digital Library" at Michigan State University, Department of Geography.

February: Michael Goodchild made a presentation entitled "Alexandria and Spatial Metadata" at the North Carolina GIS Conference in Winston-Salem.

February: Michael Goodchild presented "Finding Geography in the Digital Library" at the University of Minnesota, Department of Geography.

February: Richard Church, R. Dyrland, and K. Barber presented "Regional Ecosystem and Land Management Decision Support Tool (RELM): Demonstration of Interagency Analysis of the Northwest Forest Plan Options", at the USFS Regional Leadership Conference in Portland, Oregon.

February 3: Steve Palladino made a presentation on "GIS in the Community Colleges" for the Community Colleges for Innovative Technology Transfer GIS Conference at Pasadena City College, Pasadena, CA.

February 5: David Mark visited NSF to brief program officers on the NCGIA's new proposal. Max Egenhofer and Harlan Onsrud attended from Maine.

February 13: John E. Estes was an Invited Speaker and Panel Member at The Second International Workshop on Global Mapping, Tsukuba, Japan. His presentation was entitled "The Status of Global Mapping".

February 23: Steve Palladino organized a GIS Day for secondary school teachers involved in the UCSB QUEST National Research Lab's SPSI Program.

February 25-29: Peter Rogerson presented his paper "Surveillance Systems for Monitoring the Development of Spatial Pattern" at the 35th Annual Meeting of the Western Regional Science Association in Napa, California.

March: Barbara Buttenfield presented the paper "Real-Time Transaction Logging for Interface Evaluation" at Digital Libraries '96 (sponsored by the Association for Computing Machinery), Bethesda, Maryland.

March 2: John E. Estes made a presentation entitled "Impacts of Commercialization of Landsat on Remote Sensing Teaching and Research in U.S. Colleges and Universities" at the meeting "Universities, Research and Commercial Science and Technology: Pursuing a Competitive Agenda" in Tucson, Arizona.

March 9: Steve Palladino organized and supervised "GIS Outreach" to Oxnard College's Geo Bowl, Oxnard, CA.

March 15-16: Nectaria Tryfona attended the Conference on Object Orientation in Navigable Databases, organized by the NCGIA and the California Department of Transportation (Caltrans), Santa Barbara, CA.

March 17-26: Uwe Deichmann visited the International Rice Research Institute (IRRI) in the Phillipines to present on "Spatial Analysis and GIS in Socioeconomic Agricultural Research". His stay included a three-day seminar/workshop on spatial analysis with Spacestat and various GIS packages and discussions of IRRI research related to GIS use in farming systems studies.

March 20: David Mark presented "Representations of Geographic Space in Language, Culture and Geographic Information" at the Department of Geography, Southwest Texas State University.

March 25: Daniel R. Montello provided Invited Commentary on "Viewpoint Dependence in Human Spatial Memory" by T.P. McNamara and V.A. Diwadkar, a paper presented at the Spring Symposium on "Cognitive and Computational Models of Spatial Representation" of the American Association for Artificial Intelligence in Palo Alto, California.

March 25-29: John E. Estes presented "Commercial Potential of EOSDIS Science Data Products" at The Twenty Sixth International Symposium on Remote Sensing of Environment in Vancouver, British Columbia.

March 26-29: Max Egenhofer attended the Joint European Conference on Geographical Information, Barcelona, Spain, and presented "Open GIS = GIS on the Web".

March 27: Steve Palladino made a GIS presentation to one of the upper level math classes at Dos Pueblos High School in Santa Barbara, CA.

April: Barbara Buttenfield presented the paper "Cartography in the Next Millennium: Interface Design and Evaluation" at the American Society of Photogrammetry and Remote Sensing (ASPRS) Annual Convention, Baltimore, Maryland.

April 11-14: Munroe Eagles presented the paper he co-authored with R. Kenneth Carty, "The Political Ecology of Local Party Organization in Canada", at the British Association of Canadian Studies Annual Conference, University of Exeter, Exeter, UK.

April 9-13: Annual Meeting of the Association of American Geographers, Charlotte, North Carolina. David Mark was a panel member for "The University Consortium for Geographic Information Science: A Procedure for Determining and Promoting GIS Research Priorities", chaired the session "What is a Map?,

Revisited", and chaired the session "NCGIA Initiative 19". Michael Leitner presented the paper "The Impact of Data Quality Displays on Spatial Decision Support". David Howes presented the paper "Visualising and Predicting Urban Development Using Property Data and Satellite Imagery". The paper was co-authored by David Howes and Mike Batty. Reginald Carrol presented his paper "The Effect of Solid Waste Sites on Metropolitan Housing Values". Valerie Hartung presented the paper "Collaboration, Innovation, and Technology Diffusion in the Commercial GIS Sector". From Santa Barbara, Daniel R. Montello was an invited speaker for the panel discussion "What is a Map? Revisited". Michael Goodchild made a presentation entitled "Has GIS Killed Cartography?" in the Presidential Session. Karen K. Kemp organized and chaired a panel discussion on "On-Line Resources for GIS Education". Steve Palladino was an organizer and panelist for the session titled "GIS in the Community Colleges: Issues and Examples" and also served as a panelist for the session titled "K-12 GIS Education". John E. Estes made a presentation entitled "NASA and the New Technologies" in the session on: Selected Accomplishments in American Geography.

April 16-18: Kate Beard and Doug Flewelling attended the First Institute of Electrical and Electronic Engineers Metadata Conference, Silver Spring, MD.

April 17-21: Max Egenhofer and Harlan Onsrud attended an NSF site visit, Santa Barbara, CA.

April 22-25: Harlan Onsrud, Peggy Agouris, Tony Stefanidis, Sharron Macklin, Vyjayanti Sharma, John Florence, Michael Coan, Kenneth Roy, Paul Rosenboom, Garth McNally, and Balkaran Samaroo attended the 1996 ASPRS/ACSM Convention, Baltimore, MD. Agouris moderated a session on Remote Sensing Applications and gave a presentation in that session on "Automated Extraction of Man-Made Objects from Digital Imagery". Macklin presented "Spatial Horizons: New Directions for Secondary Education". Coan presented "The Ontology of Land Boundaries under Natural Change: Erosion and Accretion of Sandy Shoals in Nantucket Sound". Florence presented "Distribution of Topological Relations in Geographic Datasets". Barbara Buttenfield presented "Cartography in the Next Millennium: Interface Design and Evaluation".

April 25: The Buffalo GIAL hosted two tours of schoolchildren on April 25. In the morning, a group of girls, ages 9-14 toured the facility as part of "Bring Your Daughter to Work Day". In the afternoon, fifth and sixth graders from Buffalo Public School #40, which is interested in integrating geography into their curriculum, visited the facility. Approximately 100 people were involved in the two tours.

May: Michael Goodchild presented the keynote address "Directions in GIS" for GIS Technology and Applications 1996 in Taipei.

May: Peter Rogerson presented the paper, co-authored with David Plane "The Demography of Neighborhoods" at the Population Association of America conference in New Orleans, LA.

May: Barbara Buttenfield's paper "Visualizing Spatial Uncertainty" was presented at the Second International Symposium on Spatial Accuracy Assessment, Fort Collins, Colorado. Michael Goodchild presented "Communicating the Results of Accuracy Assessment: Metadata, Digital Libraries, and Assessing Fitness for Use".

May: Valerie Hartung presented the paper "Trade, Innovation, and Location: The Canadian-United States Geographic Information System (GIS) and Geomatics Sectors." at the Annual Meeting, Canadian Regional Science Association, St. Catherines, Ontario.

May 5-8: William Frank, PhD candidate, Industrial Engineering, and Rajan Batta attended the INFORMS Conference in Washington, DC. Bill Frank presented the paper he co-authored with Rajan Batta, "Models for Managing and Strategizing Route Selection for Hazardous Materials Transportation". Rajan Batta chaired the session "Routing and Location Problems Related to Hazardous Materials Transportation", and presented the paper "Analysis of Aggregation Effects on Location-Allocation" (co-authored with Peiwu

Zhao). From Santa Barbara, Richard Church presented “Special Constructs for Solving the Maximal Covering Problem using Lagrangian Relaxation”. At this same meeting, Richard Church and Mike Figueroa presented “Developing an Exploratory Search Process for a Public Sector Location Problem” and David Lemberg and Richard Church presented “Long Range School District Boundary Assignment”.

May 7-12: Harlan Onsrud attended the GISDATA specialist meeting on Geographic Information: The European Perspective, Paris, France, and presented “Intellectual Property Rights in Disseminating Digital Geographic Data, Products, and Services: Conflicts and Commonalities among European Union and United States Approaches”.

May 19-25: At the ESRI User Conference, Palm Springs, CA, Aleksey Naumov presented the paper “An approach to Building an Interface Agent for ARC/INFO”. Ezra Zubrow presented the paper “Betwixt and Between: Spatial Interpolation in Archaeology”. Ling Bian and Martin Camacho represented SUNY Buffalo under terms of their site license with ESRI, and to acquire additional knowledge of ESRI’s GIS products. Michael Goodchild made the presentation “GIS the Academic Way: New Ideas from the Ivory Tower”.

May 21-24: Nectaria Tryfona attended the Eighth International Conference on Advanced Information Systems Engineering (CAiSE '96), Heraklion, Crete, Greece, and presented “Modeling Issues to Support Interoperability in Geographic Databases”.

May 27-31: John E. Estes made a presentation entitled “Development of a Remote Sensing Core Curriculum” for the International Geoscience and Remote Sensing Symposium: Remote Sensing for a Sustainable Future (IGARSS'96) in Lincoln, Nebraska. He also presented “Remote Sensing and Core Data Needed to Support Planning and Policy Decision Making”.

May 31 - June 28: Uwe Deichmann co-taught the workshop “Geographic Information Systems for Policy Research in Population, Health and Environment”, conducted at and by the East-West Center, Program on Population in Honolulu, Hawaii.

June 2-8: Karen Kemp participated in the Virtual Geography Workshop held in Austin, Texas.

June 3-5: Max Egenhofer attended the Conference on Principles of Database Systems, Montreal, Canada, and gave a tutorial on “Geographic Database Systems: Issues and Research Needs”.

June 4: John E. Estes was an Invited Panel Participant and presented “Global Use of Remote Sensing”, GIS Technical Track, Civil Agency Applications sub-track, at TechNet '96 in Washington, DC.

June 6-8: Max Egenhofer attended an Initiative 10 research meeting, Santa Barbara, CA.

June 15-18: Max Egenhofer, Harlan Onsrud, Peggy Agouris, and Xavier Lopez attended the UCGIS annual meeting, Columbus, OH. David Mark and Ling Bian served as UB’s delegates and David Mark, as Chair of the UCGIS Research Committee, chaired the meeting. The Santa Barbara delegates were Michael Goodchild, Karen K. Kemp, and Daniel R. Montello.

June 25-July 3: Rajan Batta attended the International Symposium on Locational Decisions (ISOLDE) VII in Alberta, Canada. He presented the paper (co-authored with S. Prasad) “An Analysis of Locational Decisions for Emergency Service Facilities”. Richard Church, along with Alan T. Murray and A. Weintraub presented “Locational Issues in Forest Management”. At this same meeting, Alan Murray and Richard Church also presented “Optimizing Harvesting Operations: Locating Towers, Skidders and Roads”.

July: Helen Couclelis was the keynote speaker and participated in GISRUK ‘96 in the United Kingdom.

July: Barry Smith delivered the talk “The Metaphysics of Real Estate” at the Department of Geography/NCGIA and the talk “Introduction to Cognitive Linguistics” to the Spatial Cognition Research Group at the University of California, Santa Barbara.

July 9-19: Peggy Agouris and Anthony Stefanidis attended the International Society of Photogrammetry & Remote Sensing XVIII Congress, Vienna, Austria.

July 16-17: John E. Estes was an Invited Participant to the IGBP Land Cover Working Group Meeting, European Economic Commission, Joint Research Center in Ispra, Italy.

July 24 - August 1: Harlan Onsrud attended the Young Scholars Summer Institute in Geographic Information, Berlin, Germany. Michael Goodchild made a presentation entitled “Multiple Roles for GIS in Global Change Research” and Helen Couclelis also attended the Institute.

July 30 - August 1: John E. Estes and A. Singh were Invited Co-Chairs, Global Learning and Observations to Benefit the Environment (GLOBE), Science Workshop, Airlie House, Virginia.

August: Michael Goodchild presented the Keynote Address at the 1996 Genasys Conference in Fort Collins, Colorado.

August: Michael Goodchild made the presentation entitled “Digital Libraries and Spatial Information Processing” at IRREGULAR ‘96 in Santa Barbara, California.

August: Michael Goodchild presented “GIS, Spatial Analysis, and Interoperability” at the International Geographical Congress, The Hague.

August 6: Steve Palladino organized and directed a GIS day for Science Teachers involved with the UCSB QUEST program, Science in Action.

August 12-17: Max Egenhofer attended Spatial Data Handling 1996 in Delft, The Netherlands. Ashton Shortridge presented a paper co-authored with Charles E. Ehlschlaeger entitled “Modeling Elevation Uncertainty in Geographical Analysis”. Kevin Curtin and Peter Fohl presented “A non-planar, lane-based navigable data model for ITS”.

August 11-12: Steve Palladino organized and directed the California GIS Educators' Symposium held at the University of California, Santa Barbara.

August 12-18: Steve Palladino coordinated and directed the Working Session for the ATE Project, University of California, Santa Barbara.

August 13: John E. Estes presented “Overview of Available Remote Sensing Technologies Useful For Oil Spills” at the Alaska Satellite Applications Workshop, Alaska Pacific University, Anchorage, Alaska.

August: Barry Smith delivered the talk “The Cognitive Geometry of War” at Current Issues in Political Philosophy: Justice and Welfare in Society and World Order, 19th International Wittgenstein Symposium, Kirchberg am Wechsel, Austria.

August 20: John E. Estes served as the Invited Chair, Plenary Session 1, and Moderator of the luncheon panel discussion for Pecora 13: Human Interactions with the Environment: Perspectives From Space in Sioux Falls, South Dakota. He also made a presentation “Accuracy Analysis of Global 1-Km Land Cover Data Sets - Current North American and Africa Data Set Cross Validation”.

August 28: David Mark, Rajan Batta, Peter Rogerson, Emil Boasson and Steven Parkansky visited the Buffalo Police headquarters to discuss their use of GIS technology and possible partnerships with the NCGIA.

August 29 - Sept. 1: Munroe Eagles attended the meeting of the American Political Science Association, San Francisco, CA, and presented the paper "Pedagogical Strategies and Assessment Results in Cross-National Simulations: Conclusions From a Two-Continent Model European Union Simulation" (co-authored by Eagles, Henry Steck, Laurie Buonanno Lanze)

September: Michael Goodchild presented "Directions in GIS" at the University of Michigan.

September 5-7: The paper "Community-based GIS Education: A Twin Cities Experiment" (McMaster, Robert B. Helga Leitner, Eric Sheppard, and Sarah Elwood) was presented at the 2nd International Symposium on GIS in Higher Education. Baltimore, MD. Sharron Macklin attended the conference from Maine. Karen Kemp was conference chair. Steve Palladino was a member of the Steering Committee and made two presentations addressing the Core Curriculum for Technical Programs project. A conference summary has been posted on the NCGIA web site at http://www.ncgia.ucsb.edu/conf/GISHE/main.html.

September 9-11: Helen Couclelis chaired the Steering Committee, participated in, and served as the Conference Coordinator for "Spatial Technologies, Geographic Information, and the City: A Research Conference" held in Baltimore, Maryland. Reginald Golledge and David Lemberg of NCGIA Santa Barbara were also participants.

September 19: Meghan Cope served as a Panelist in the Interdisciplinary Workshop "Roundtable on Reform of Welfare", hosted by Baldy Program on Community and Difference, Baldy Center for Law and Social Policy, SUNY-Buffalo.

Sept. 25: PhD student Emil Boasson delivered an invited lecture on Geography and GIS at the Geoscience Department of the University of Iceland in Reykjavilk, Iceland. He also delivered an invited talk on "New Trends in GIS" at the Association of Icelandic Geographers.

September 25-27: John E. Estes was an Invited Participant at the "National Environmental Monitoring and Research Workshop", part of the National Environmental Monitoring Initiative, under the National Science and Technology Council's Committee on Environment and Natural Resources, Washington DC.

October: John Krygier was invited to attend a symposium/panel discussion on the role of geographic visualization and public participation, Syracuse, NY. He was sponsored by SUNY ESF.

October: John Krygier was invited to attend a day long symposium on community networks sponsored by the USDA and Clinton County, in Lock Haven PA.

October: Barry Smith gave either the talk "Extreme Compatibilist Mereotopological Realism" or the talk "Categories Deep and Superficial", or perhaps both, at the Department of Philosophy, York University, Toronto.

October: Barbara Buttenfield presented "The Human Component of an Internet Digital Map Library: Re-Thinking User Interface Evaluation" at the Annual Meetings, North American Cartographic Information Society, San Antonio, Texas.

October: Barry Smith gave the talk "The Metaphysics of Real Estate" to the Department of Philosophy, Texas Technical University, Lubbock, Texas; and the talk "On the Origins of War", at the Philosophy Club, Texas Tech, University, Lubbock, Texas.

October 17: NCGIA-supported researchers at the University of Minnesota held two workshops "GIS for environmental risk analysis" at Citizens for a Better Environment, Minneapolis, MN.

October 21-22: Harlan Onsrud was invited to attend "The Role of GIS for the Enhancement of National Spatial Planning" conference, Jakarta, Indonesia, and presented "US and European Perspectives Across a Range of Legal Topics of Spatial Data".

October 25: Max Egenhofer visited Oracle Corp., Nashua, NH, and gave a talk on "Research Issues in Spatial Database Issues".

October: Paul Sutton presented "Estimation of the Total Value of Global Ecosystem Services and Natural Capital" with Bob Costanza at a National Center for Ecological Analysis and Synthesis (NCEAS) workshop in Santa Barbara.

October 23-25: John E. Estes was an Invited Participant for the workshop entitled "Remote Sensing in Agriculture in the 21st Century" at the University of California, Davis.

October 30 - November 2: Max Egenhofer, Kathleen Hornsby, and Martin Raubal attended the NCGIA Initiative 21 Specialist Meeting, San Marcos, TX.

November: Barry Smith Delivered the presentation "Ontology, Epistemology and the Parceling of Space" at the International Conference on Comparative (Cross-Cultural) Ontologies for Cadastral Systems, Department of Geoinformation, Technical University of Vienna, Austria.

November: Barry Smith delivered the paper he had co-authored with Leo Zaibert "Sovereignty and Property Rights" at the Department of Political Science, University of Olomouc, Czech Republic.

November: Rajan Batta attended the INFORMS conference in Atlanta and delivered the paper he had co authored with C. Eagen, "Practical Hazardous Materials Routing Under Insurance Parameters".

November: Keith Clarke was the keynote speaker for the ESRI NorthWest Users Group Meeting held in November in Oregon.

November: Michael Goodchild presented the keynote address "The Past and Future of Geographic Information Technologies" at the GIS in Illinois 1996 Conference, Schaumburg, Illinois. At this conference, he also presented "Accuracy of Spatial Databases".

November 4: John E. Estes was an Invited Speaker and presented "The Mythical Map" to the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America Annual Meeting in Indianapolis, Indiana.

November: Michael Goodchild presented "GIS as a Research Technology" for a Workshop on GIS Applications in Cancer Research in Washington, DC.

November 12-14: Harlan Onsrud attended the Land Tenure and Administration Conference, Orlando, FL.

November 13-16: Max Egenhofer attended the Association of Computing Machinery's workshop on Geographic Information Systems, Rockville, MD.

November 13-16: Steve Palladino was a key organizer of the National Council for Geographic Education (NCGE) Annual Meeting which took place in Santa Barbara. He organized and presented a number of sessions, including two on "Defining Community College Gegoraphy: Building a Framework", a review of the Core Curriculum for Technical Programs, and a computer workshop entitled "A Collection of GIS and

Computer Learning Modules". Karen Kemp organized a full session on the three new Core Curricula. Paul Sutton and Paul Van Zuyle presented "Using ArcView-Based Learning Modules in the Classroom".

November 13-16: John E. Estes was a co-organizer, session chair, and speaker at the Interregional Seminar on Global Mapping for the Implementation of Multinational Environmental Agreements, sponsored by the United Nations and the Ministry of Construction, Geographical Survey Institute, Japan; and hosted by the University of California, Santa Barbara.

November 14-17: The Annual Meeting of Regional Science Association International , Washington, DC. Peter Rogerson presented the paper "A Spatial Version of the Chi-Square Goodness-of-Fit Test and its Application to Tests for Spatial Clustering". PhD student Valerie Hartung presented her paper "The Role of Information Networks: Mapping Inter-Firm Linkages in the Geographic Information Systems Industry".

November 16-17: Steve Palladino organized and participated in a specialist meeting on K-12 GIS research issues. The meeting, entitled "EDGIS '96", took place in Santa Barbara immediately following the NCGE Annual Meeting.

November 18. David Mark and Ling Bian represented UB at the UCGIS annual meeting in Denver, Colorado . Mark was elected Vice President of UCGIS, to become President for 1998.

November 19-21: GIS/LIS '96, Annual Conference, Denver, Colorado. David Mark presented the paper "Common-Sense Geography: Foundations for Intuitive Geographic Information Systems". He also was a panel member for the session "University Consortium for Geographic Information Science: 1997 Research Priorities". Ling Bian presented the paper "Effects of watershed discretization on estimating hydrologic parameters". Researchers working on projects related to I17 participated in a special session at GIS/LIS '96. Karen Kemp (UCSB) organized the session and served as session chair. The following papers were presented and also published in the Proceedings of GIS/LIS '96: M.P. Armstrong and R.J. Marciano, "Distributed parallelism: impacts on GIS and collaborative spatial decision-making"; C.D. Ellis, D.M. Johnston and L.D. Hopkins, "Ethnographic assessment of ecological modelers for design of a collaborative geographical modeling system"; D.S. Lemberg and R.L. Church, "Feasible alternatives generation in collaborative spatial decision making"; P. Jankowski and M. Stasik, "Architecture for space and time distributed collaborative spatial decision making". The paper co-authored by B.E. Cramer and M.P.. Armstrong, "A Distributed Parallel Approach to Computation of a Spatial Statistic", was also presented at the meeting. Harlan Onsrud attended the conference from Maine. From Santa Barbara, Michael Goodchild presented "Generalization, Uncertainty, and Error Modeling" and Karen Kemp organized a full session on the three new Core Curricula. John E. Estes was organizer and a speaker for the session on Monitoring Global Change, The Need for Global Baselines.

December: Michael Goodchild presented "GIS Research" to the Department of Surveys and Land Information in Cape Town, South Africa.

December: Michael Goodchild presented "The Past and Future of Geographic Information Technology" at GEO FORUM '96 in Bakersfield, CA.

December 4: David Mark and Munroe Eagles traveled to Albany to serve as panelists in a video course on grant writing. The project was developed by the SUNY Faculty Senate and Professors Mark and Eagles were invited to serve on the Social and Behavioral Sciences panel.

December 15-17: Kate Beard attended the NSF Digital Libraries meeting, San Francisco, CA.

December 18: David Howes (PhD candidate) delivered the invited talk "Modelling Spatial Variability of Infiltration" at the Department of Geography seminar, University of Dundee, Scotland.

APPENDIX 3 - VISITORS TO NCGIA SITES

Teresa Adams, University of Wisconsin, Madison
Stuart Aitken, San Diego State University
Dave Alba, Buffalo Police Department
William Albert, Boston University
Jochen Albrecht, University of Vechta
David Arctur, Laser-Scan, Inc.
Matatoshi Arikawa, Hiroshima City University
Marc Armstrong, University of Iowa
Lawrence Ayers, Intergraph Corp
François Bancilhon, O2 Technology
Larry Band, University of Toronto
Greg Barker, Thousand Oaks High School
Renato Barrera, Intergraph Corp
Felix Barreto, California Polytechnic State University
Yakup Basmaci, Izmir Water and Sewerage Administration, Turkey
Bernard Bauer, UCLA
Eric Bayer, Intergraph Corporation
Hank Beaver, San Diego Mesa College
Josef Benedikt, University of Vienna
Stephen Bespalko, Sandia National Laboratories
Rick Block, Montana State University
Istvan Bodnar, University of Budapest
Luis A. Bojorquez-Tapia, National Autonomous University of Mexico
Robert Bootsma, Testbed Center for Interoperability, UCSB
Kushal Bordoloi, Intergraph Corporation
Earl Bossard, San Jose State University
Rosemary Bowker, California Polytechnic State University, San Luis Obisbo
Les Bowker, California Polytechnic State University, San Luis Obisbo
Kurt Buehler, Open GIS Consortium
Lauretta Burke, Institute for Public-Private Partnerships
Barbara Buttenfield, University of Colorado, Boulder
Daniel Carlson, National Engineering Technology Corporation
Irene Campari, Geoinformation, Technical University Vienna
Changhua Cen, Beijing Research Institute of Uranium Geology
Pak Chagarlamudi, National Resources Canada
Tai On Chan, University of Melbourne
Pamela Chapman, San Diego Mesa College
Nick Chrisman, University of Washington
Robert M. Christie, CSU Dominguez Hills
Antony G. Cohn, University of Leeds
Edward Collins, Sandia National Laboratories
Michael Curry, UCLA
Jack Dangermond, ESRI
Ann Deakin, SUNY Fredonia
Craig Dean, Sandia National Laboratories
Liu Dechang, Nuclear Industry Beijing Reserach Institute of Geology
Samuel DeFazio, Oracle Corporation
Craig Denison, Caltrans
Paul Densham, University College London
Zachary Deretsky, ETAK Inc.
Akash Deshpande, University of California, Berkeley

Les Doak, North Orange County Community College District
Holly E. Dodson, University of California, San Diego
Roger Downs, Pennsylvania State University
Feridun Duyguluer, Ministry of Public Works, Turkey
Robert Edwards, Cabrillo College
Chuck Ehlschlaeger, University of Cincinnati
Mehmet Emin Ekinci, Delvet Liman ve Hava Meydanlari Insaati Genel Mudurlugu, Turkey
Hulya Eksert, Antalya Municipality, Turkey
J. Nicholas Entrikin, UCLA
David C. Etter, Bay Area Shared Information Consortium
Boi Faltings, Swiss Federal Institute of Technology, Lausanne
Ma Fei, Beijing Research Institute of Uranium Geology
Jeff Fleischer, Central Intelligence Agency
David Fletcher, University of New Mexico
Pip Forer, University of Canterbury
Stewart Fotheringham, University of Newcastle-upon-Tyne
Lawrence Fox, Humboldt State University
Andrew U. Frank, Geo-Information, Technical University Vienna
Michael Franklin, University of Maryland
Christian Freksa, Universität Hamburg
Scott M. Freundschuh, University of Minnesota
Jesus Garcia, Kern County Superintendent of Schools
Paul Gessler, CSIRO
Peter Gill, Council for Scientific and Industrial Research (CSIR), South Africa
Victor Goldsmith, Hunter College
Lola Goljamova, Tashkent, Uzbekistan
Craig Gooch, Psomas and Associates
Cecil Goodwin, Viggen Corporation
Stephen Gordon, Martin Marietta
Jon Goss, University of Hawaii
Frank Gossette, California State University, Long Beach
Carlo Giupponi, University of Padova
Ronald Hagelberger, Amherst Police Department
Karl Halbach, Santa Barbara City College
Erin Hall, Geo InSight International
J.W. Harrington, NSF
Britton Harris, University of Pennsylvania
Francis Harvey, Swiss Federal Institute of Technology
Bill Hazelton, Northern Territory University, Australia
Asil Hekimoglu, Delvet Su Isleri, Turkey
John Herring, Oracle Corporation
Stephen Hirsch, MITRE Corporation
Stephen C. Hirtle, University of Pittsburgh
David Hodge, University of Washington
Brian P. Holly, Kent State University
Tom Holst, Columbia College
Dale Honeycutt, ESRI
Ron Horvath, University of Sydney
Carolyn Hunsaker, ORNL
Fuat Ince, Tubitak Marmara Research Center, Turkey
Kazutaka Iwasaki, Hokkaido University
Capt. Jamaresi, Buffalo Police Department
Jan Juul Jensen, National Environmental Research Institute, Denmark
Frank Jones, InterMAPhysics

Paul Kanciruk, ORNL
Jagat Singh Kathayat, Wildlife Institute of India
John Kelmelis, USGS
Victor Klemas, University of Delaware
Harrik Kiiveri, CSIRO
Philip Kilby, CSIRO/DIT
Tuba Kiper, Kara Yollari Genel Mudurlugu, Turkey
Temel Kotil, Istanbul Municipality, Turkey
Werner Kuhn, Technical University, Vienna
John Landis, University of California, Berkeley
Siu-Wah Lau, UCLA
Yun K. Lee, CSU Fullerton
Tom Leinbach, NSF
Richard Lewis, Trimble Navigation
Bin Li, University of Miami
Thomas Lillesand, University of Wisconsin
David Lively, Caltrans
William J. Lloyd, California State University, Fullerton
Hong Lo, Hong Kong University of Science and Technology
Mindy Lorenz, Geo InSight International
Jamson Lwebuga-Mukasa, Buffalo General Hospital
David Maidment, University of Texas
Hideo Makino, Niigata University
Ken McGwire, Defense Research Institute, Las Vegas
Patrick McHaffie, DePaul University
Jeff McRae, Caltrans
Michael J. Melton, Amherst Police Department
Bob Merisco, Central Intelligence Agency
Colleen Mesel, California State University, Bakersfield
Jeff Meyer, California Lutheran College
R.K. Midha, Ministry/Department of Science & Technology, New Delhi
Roger Miller, University of Minnesota
Hidefusa Miyama, PASCO Corporation
Rafael Morano, University of Western Ontario
Cathy Mueller, ESRI
Kevin S. Neumaier, Ecology and Environment, Inc.
Susan L. Nolen, Intergraph Corp
Dave Nystrom, USGS
Colleen O'Connor, San Diego Mesa College
Morton O'Kelley, Ohio State University
John Odland, Indiana University
Toshi Okuyami, PASCO Corporation
Dick Olson, ORNL
Erol Omer, Commercial Service, Turkey
Morishige Ota, Kokusai Kogyo Co., Ltd.
Yusuf Ozturk, Navigation Technologies
Joe Palen, Caltrans
Jack Paris, California State University, Fresno
Randy Paul, Central Intelligence Agency
Micha Pazner, University of Western Ontario
Donna Peuquet, Pennsylvania State University
Michael Phoenix, ESRI
John Pickles, University of Kentucky
Patrick Pidgeon, San Diego Mesa College

Jim Plasker, USGS
Juval Portugali, Tel Aviv University
Robert Raskin, University of California, Santa Cruz
Tom Rauch, UC Berkeley Extension
David Rhind, Director General and Chief Executor, Ordnance Survey of Great Britain
Mr. Richardson, Central Intelligence Agency
Andreas Riedl, Simon Fraser University
Timothy Robinson, National University of Costa Rica
Alex Rodarte, National Engineering Technology Corporation
H. J. Ross, Luxemburgo, Brazil
Gerard Rushton, Ohio State University
Shogo Sakakura, PASCO Corporation
Mauro, Salvemini, University of Rome
Ramiro Sanchez, Santa Barbara City College
Jay Sandhu, ESRI
Robert R. Santa Maria, Ecology and Environment, Inc.
M.M.K. Sardana, Ministry/Department of Science & Technology, New Delhi
Hasan Zuhuzi Sarikaya, Istanbul Water and Sewerage Administration, Turkey
Tapani Sarjakoski, Finnish Geodetic Institute
Ken Satou, PASCO Corporation
Jan Schultz, Santa Barbara City College
Louis Schell, Chabot Observatory and Science Center
Eddie C. Shek, UCLA
Shashi Shekhar, University of Minnesota
Michael Shiffer, Massachusetts Institute of Technology
Asfand Yar Siddiqui, Caltrans
Charr Simpson-Smith, Cabrillo College
Ratna Singh, Wildlife Institute of India
Stephen Smyth, Microsoft Corporation
Kermit Snelson, Etak, Inc.
Bruce Spear, Bureau of Transportation Statistics
Stephen Derek Stead, University of Leicester
Ann Stefani, San Bernardino Valley College and Saddleback College
Frank Stolle, University of Massachusetts at Amherst
Seong-Mu Suh, Chung-Ang University, Seoul
John Sutton, GIS/Trans., Ltd.
Agatha Tang, ESRI
Derek Thompson, University of Maryland
Jeff Tolhurst, Columbia College
Mark Trembley, San Diego Mesa College
Nectaria Tryfona, University of Maine
Gene Turner, California State University Northridge
Barbara Tversky, Stanford University
Nurinisa Usul, Middle East Technical University, Turkey
Dalia Varanka, U.S. Department of the Interior, Bureau of Land Management
Parvatham Venkatachalam, Indian Institute of Technology (IIT) in Bombay
Alan Vonderohe, University of Wisconsin
Jess Walker, Louisiana State University
Ed Waltz, Environmental Research Institute of Michigan
Ben Weaver, San Diego Mesa College
Doug Willier, Institute for Public-Private Partnerships
Cort Willmott, University of Delaware
Mike Wilson, SUNY Fredonia
Mike Worboys, Keele University

Kathy Wortman, USGS
Richard Wright, San Diego State University
Scott Wright, Gallium Software Inc.
Juang Xianfang, Beijing Research Institute of Uranium Geology
R.N. Yadava, Regional Research Laboratory Bhopal (CSIR) India
Ali Zaghari, Caltrans
Aurang Zeb, Oregon State University
Ming Zhang, University of California, Berkeley

APPENDIX 4 - COURSES TAUGHT BY NCGIA FACULTY

1. Santa Barbara

Physical Geography, Winter 1996, Terry Smith
Socioeconomic Geography, Winter 1996, Daniel Montello
Introduction to Environmental Optics Physical Geography, Winter 1996, Dar Roberts
Introduction to Spatial Decision Making and Behavior, Winter 1996, Michael Costanza
Introduction to Meteorology, Winter 1996, Joel Michaelsen
World Soils, Winter 1996, Oliver Chadwick
Geographic Remote Sensing Techniques, Winter 1996, Leal Mertes
Groundwater Hydrology, Winter 1996, Hugo Loaiciga
Introduction to Cartography, Winter 1996, Violet Gray
Ocean Remote Sensing, Winter 1996, Libe Washburn
Rivers, Winter 1996, Leal Mertes
Geography of the United States, Winter 1996, John E. Estes
Biogeography: The Study of Plant and Animal Distributions, Winter 1996, Frank Davis
Surface Climate and Water Relations of Soils and Vegetation, Winter 1996, Dar Roberts
Introduction to Geographical Data Analysis, Winter 1996, Daniel Montello
Technical Issues in Geographic Information Systems, Winter 1996, Michael Goodchild
Geography Planning and Policy Making, Winter 1996, David Lemberg
The Idea of Nature, Winter 1996, James Proctor
Introduction to Geographic Research, Winter 1996, Joel Michaelsen and James Proctor
Seminar in Geography, Winter 1996, Joel Michaelsen
Remote Sensing and Environmental Optics, Winter 1996, Dar Roberts
Seminar in Physical Geography, Winter 1996, Thomas Dunne and Jeff Dozier
Urban Problems, Winter 1996, Helen Couclelis
Earth System Science: The Hydrologic Cycle, Winter 1996, Hugo Loaiciga
Earth System Science: Energy and Radiation, Winter 1996, Catherine Gautier
Introduction to Physical Oceanography, Winter 1996, David Siegel
Seminar in Oceanography, Winter 1996, Thomas Dickey
Introductory Human Geography, Spring 1996, James Proctor
Soil Genesis and Classification, Spring 1996, Oliver Chadwick
Intermediate Geographic Remote Sensing Techniques, Spring 1996, Leal Mertes
Production Cartography, Spring 1996, Violet Gray
Tropical Meteorology, Spring 1996, Alexander Gershunov
Earth System Science, Spring 1996, Catherine Gautier
Water Pollution, Spring 1996, Hugo Loaiciga
Waves and Tides in the Ocean, Spring 1996, Hugo Loaiciga
Introduction to Vegetation Analysis, Spring 1996, Frank Davis
Applications of GIS Technology, Spring 1996, Michael Goodchild
Location and Environmental Issues in Planning, Spring 1996, Richard Church
Pedology, Spring 1996, Oliver Chadwick
Digital Techniques in Remote Sensing, Spring 1996, Leal Mertes
Seminar in Remote Sensing, Spring 1996, John E. Estes
Cognitive Issues in Geographic Information Science, Spring 1996, Daniel Montello
Field Seminar in Snow Science, Spring 1996, Jeff Dozier
Earth Systems Science: Ocean-Atmosphere Dynamics, Spring 1996, Thomas Dickey
Introduction to Geographical Data Analysis, Spring 1996, Joel Michaelsen
California, Summer 1996, Michael Costanza
Computational Concepts in Geography, Fall 1996, Joel Michaelsen
Physical Geography of the World's Oceans, Fall 1996, Libe Washburn
Urban Geography, Fall 1996, Helen Couclelis

Environmental Hydrology, Fall 1996, Hugo Loaiciga
Introduction to Soil Science, Fall 1996, Oliver Chadwick
Geographic Photo Interpretation, Fall 1996, John E. Estes
Research Methods in Human Geography, Fall 1996, Daniel Montello
Introduction to Transportation Systems Analysis, Fall 1996, Richard Church
Geography of the California Current, Fall 1996, David Siegel
Introduction to Geographic Information Systems, Fall 1996, Keith Clarke
Human-Induced Environmental Change, Fall 1996, James Proctor
Seminar in Geography, Fall 1996, Reginald Golledge
Analytical Methods for Geographers, Fall 1996, Joel Michaelsen
Advanced Remote Sensing, Fall 1996, Dar Roberts
Environmental Perception and Cognition, Fall 1996, Reginald Golledge
Earth System Science, Fall 1996, Catherine Gautier
Ocean Optics, Fall 1996, David Siegel
Quantitative Biogeography, Fall 1996, Frank Davis
Human-Induced Environmental Change, Fall 1996, James Proctor
Advanced Topics in Pedology, Fall 1996, Oliver Chadwick

2. Maine

Land Development Design, Spring 1996, Harlan Onsrud
Community Information System Design, Spring 1996, Kate Beard
Environmental Law and Resource Regulation, Spring 1996, Harlan Onsrud
Geometry for Geographic Information Systems, Spring 1996, Max Egenhofer
Selected Studies - GIS Applications, Spring 1996, Kate Beard
Selected Studies - Internet Program Applications, Spring 1996, Kate Beard
Graduate Seminar, Spring 1996, Harlan Onsrud
Principles of Information Systems, Spring 1996, Max Egenhofer
GIS Applications, Spring 1996, Kate Beard
Selected Studies - Practical Training in GIS, Spring 1996, Beard
Adjustment Computations, Fall 1996, Peggy Agouris
Remote Sensing, Fall 1996, Peggy Agouris
Engineering Databases and Information Systems, Fall 1996, Max Egenhofer
Introduction to Graduate Research, Fall 1996, Max Egenhofer
Spatial Analysis, Fall 1996, Kate Beard
Information Systems Law, Fall 1996, Harlan Onsrud
Graduate Seminar, Fall 1996, Harlan Onsrud
Graduate Thesis, Fall 1996, Harlan Onsrud
Selected Studies - Applications on ArcInfo, Fall 1996, Kate Beard
Selected Studies - Digital Image Processing, Fall 1996, Peggy Agouris
Selected Studies - GIS Projects, Fall 1996, Kate Beard
Selected Studies - Practical Training, Fall 1996, Kate Beard
Selected Studies - Digital Spatial Libraries, Fall 1996, Kate Beard
Selected Studies - GIS/Hydrology, and Environmental Applications, Fall 1996, Kate Beard
Selected Studies - Metadata for Surveying Measurements, Fall 1996, Kate Beard
Selected Studies - Image Analysis, Fall 1996, Peggy Agouris
Selected Topics - Algebraic Specification, Fall 1996, Max Egenhofer

3. Buffalo

Advanced Biogeography, Spring 1996, Larsen
Geographic Algorithms and Data Structures, Spring 1996, Mark
Geography Seminar, Spring 1996, Cope
GIS and Environmental Modeling, Spring 1996, Bian

Industrial Geography, Spring 1996, Bagchi-Sen
Introduction to Human Geography, Spring 1996, Cope
Introduction to Physical Geography, Spring 1996, Woldenberg
Mathematical Models in Social Science, Spring 1996, Cole
Multivariate Statistics, Spring 1996, Rogerson
Remote Sensing, Spring 1996, Bian
Spatial Decision Support Systems, Spring 1996, Cole
Spatial Problems of Multinational Operations, Spring 1996, Bagchi-Sen
Geo/Cartographic Visualization, Fall 1996, Krygier
Geographic Information Systems (Graduate), Fall 1996, Mark
Geographic Information Systems (Undergraduate), Fall 1996, Bian
Geographic Perspectives and World Issues, Fall 1996, Calkins
Geography Honors Program, Fall 1996, Rogerson
Geostatistics, Fall 1996, Bian
GIS Design, Fall 1996, Calkins
International Environment and Commercial Problems, Fall 1996, Bagchi-Sen
Introduction to Graduate Geography, Fall 1996, Woldenberg
Introduction to Human Geography, Fall 1996, Cope
Landform Development, Fall 1996, Woldenberg
Landscape Ecology, Fall 1996, Larsen
Multivariate Statistics Fall 1996, Rogerson
Physical/Environmental Geography, Fall 1996, Larsen
Regional Analysis, Fall 1996, Cole
Univariate Statistics in Geography, Fall 1996, Rogerson
Urban Geography, Fall 1996, Bagchi-Sen
Urban Geography Models, Fall 1996, Thill
Urban Social Geography, Fall 1996, Cope

APPENDIX 5 - GRADUATE DEGREES GRANTED AT NCGIA SITES

1. Santa Barbara

CULLEN, Stephen, Ph.D., Winter 1996, Field and Laboratory Investigations of Contaminant Natural Attenuation and Intrinsic Remediation in Soils and the Vadose Zone (Loaiciga, Davis, Michaelsen, Everett).

DEICHMANN, Uwe, Ph.D., Winter 1996, A Spatial Analysis of Technology Adoption in Sub-Saharan Farming Systems (Anselin, Goodchild, Tobler, Lynam).

FELKNER, John, M.A., Fall 1996, An Analysis of International Data Exchange Policy (Goodchild, Dozier, Estes).

FIGUEROA, Michael, M.A., Spring 1996, Construction of an Exploratory Modeling System for Public Sector Location-Allocation Planning (Church, Goodchild, Couclelis).

GALINSKY, Kevin, M.A., Winter 1996, Degree by examination (Washburn, Siegel, Michaelsen).

GERSHUNOV, Alexander, Ph.D., Winter 1996, Large-Scale Variability of Tropospheric Moisture and Climatic Implications (Michaelsen, Gautier, Siegel, Leskow).

HENDERSON, Thomas, Ph.D., Winter 1996, An Analysis of the Effects of Ground Parameters and Multitemporal Compositing Techniques on the Passive Microwave Vegetation Index (Estes, Mertes, Lanter, Neale).

LAWLESS, Michael, M.A., Fall 1996, Potential Commercial Applications of EOS Science Data Products (Estes, Goodchild, Roberts).

MERCHANT, George, M.A., Winter 1996, Conservation Principles and the Initiation of Channelized Surface Flows (T. Smith, Mertes, Siegel).

PAINTER, Thomas, M.A., Fall 1996, Improving Spectral Mixture Analysis of Snow-Covered Area from AVIRIS Data (Dozier, Roberts, Gautier).

PATTERSON, Karen, M.A., Fall 1996, Calculation of Biologically Effective UV Dose Rates for Larval Anchovies in the Southern California Bight Using PUV Data in Combination with a Simple High-Spectral Resolution Model (R. Smith, Siegel, Gautier).

SORENSEN, Jens, M.A., Spring 1996, Variability and models of the effective quantum yield of carbon assimilation in the Sargasso Sea (Siegel, R. Smith, Washburn).

TAKEYAMA, Masanao, Ph.D., Winter 1996, GEO-ALGEBRA: A Mathematical Approach to Integrating Spatial Modeling and GIS (Couclelis, Goodchild, Tobler, Batty).

THOMAS, Kathryn, Ph.D., Winter 1996, Vegetation and Floristic Diversity in the Mojave Desert of California: A Regional Conservation Evaluation (Davis, Michaelsen, Goodchild, Mahall).

TUCHBAND, Dana, M.A., Spring 1996, Comparing Linear and Nonlinear Rainfall-Runoff Models in the Steep Mountain Catchments of Santa Barbara County, California (Loaiciga, Chadwick, Clark).

VALERIANO, Dalton, Ph.D., Spring 1996, Relationships Between Tropical Forest Structure and Remotely Sensed Synthetic Aperture Radar Data (Davis, Melack, Dozier, Mertes).

2. Maine

COAN, Michael, M.S., August 1996, Spatial Information Science and Engineering.

HAGOPIAN, Daniel, M.S., December 1996, Spatial Information Science and Engineering.

HALL, Gregory, M.S., May 1996, Spatial Information Science and Engineering.

LOPEZ, Xavier, Ph.D., 1996, The Impact of Government Information Policy on the Dissemination of Spatial Data: A North American - European Comparative Study.

MACKLIN, Sharron, M.S., December 1996, Spatial Information Science and Engineering.

MARTH, Nancy, M.S., December 1996, Spatial Information Science and Engineering.

RAMLAL, Bheshem, Ph.D., 1996, A Data Quality Model for the Representation of Mixed Spatial Variation.

SHARIFF, Abdul Rashid Bin Mohamed, Ph.D., Summer 1996, Natural-Language Spatial Relations: Metric Refinements of Topological Properties.

SHARMA, Jayant, Ph.D., 1996, Integrated Spatial Reasoning in Geographic Information Systems: Combining Topology and Direction.

ZEINER, Kelly, M.S., August 1996, Spatial Information Science and Engineering.

3. Buffalo

DEAKIN, Anne, Ph.D., June 1996, The Impact of the 1994 Northridge Earthquake on Los Angeles (Mark, Buttenfield, Cole, Batty)

FINNERAN, Christina M. Finneran, M.A., September 1996, A Needs Assessment Software Tool: Assisting Municipalities with Designing Successful Geographic Information Systems (Calkins).

HART, William, M.A., September 1996, The Need for GIS for Counter Drug Interdiction (Mark).

JANAK, Jeff, M.A., June 1996, An Evaluation of the Effectiveness of the Gentool Application (Buttenfield, Mark)

LAIRD, Richard, M.A., September 1996, Design and Implementation of an Entity-Relationship Diagramming System for Use in Designing Geographic Databases (Calkins).

LEITNER, Michael, Ph.D., October 1996, The Impact of Data Quality Displays on Spatial Decision Support (Buttenfield, Mark, Woldenberg, McGranaghan).

LIN, Ge, Ph.D., June 1996, Intergenerational Proximity: A Life Cycle Analysis of Migration Propensity and Consequesce (Rogerson, Bagchi-Sen, Burr, Watkins)

MARSTERS, Robert, M.A., February 1996, Real Estate Geographic Information System (REGIS): Residential Real Estate Sales Application (Calkins).

MOFFE, James Daniel, M.A., September 1996, The Location and Diffusion of Microbreweries in the United States (Rogerson).

PLEWE, Brandon, Ph.D., March 1997, Cartographic and GIS Representations of Gradation (Buttenfield).

RICCI, Victor, M.A., February 1996, The Digital Environment: Legal Impediments to the Structure of Information (Buttenfield, Woldenberg).

SUKARTO, Sandy, M.A., February 1996, Opportunities for Canadian Computer Peripheral Product Companies in Upstate New York (Bagchi-Sen).

TSOU, Ming-Hsiang, M.A., February 1996, Object-Oriented Approaches in Graphic User Interface Design for the Visualization of Information Processing and Analysis in GIS (Buttenfield, Mark).

VOLPE, Jeffrey, M.A., September 1996, Metadata Review and Analysis for the Erie County Water Authority's Geographic Information System (Calkins).

WEATHERBE, Richard, Ph.D. (posthumously), Organizational Characteristics and Issues in the Sharing of Geographic Data (Calkins, Rogerson, Woldenberg).

WILLIAMS, Erik, M.A., February 1996, Climate and North American Plant Formations: Associations Between the Water Balance and Satellite-Derived Vegetation Patterns (Mark, Jelinski).

ZENT, Christopher, M.A., September 1996, TIGER vs. DLG Road Feature Data (Mark).

ZHAO, Peiwu, Ph.D., June 1996, Analysis of Aggregation Effects in Location Problems (Batta, Karwan, Ramesh, Rogerson).