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NCGIA Closing Reports on Research Initiatives and Projects

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NATIONAL CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS

ANNUAL REPORT

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

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

February 28, 1993

NATIONAL CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS

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SUMMARY

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

This document reports on the Center's fourth full year of operation. The life cycles of the first three Center research initiatives came to an end with the acceptance of their closing reports by the Board of Directors: Accuracy of Spatial Databases (I1, begun in December 1988); Languages of Spatial Relations (I2, begun in January, 1989); and Multiple Representations (I3, begun in February, 1989). New initiatives were begun in Institutions Sharing Spatial Information (I9) and GIS and Spatial Analysis (I14). In the education area, the Center launched its Secondary Education Program with a workshop for high school teachers in Santa Barbara in July. Conferences were organized on GIS applications in anthropology and political science. Awareness of the Center and its activities continues to grow, and NCGIA was instrumental in helping launch a European GIS research program under the auspices of the European Science Foundation.

Year Four saw an extended process of evaluation of the Center's renewal proposal to NSF, submitted in November, 1991, and covering the period through 11/30/96, *i.e.* for years 6-8. A site visit in June, 1992 focused on the Center's role as a national center for geography, and its willingness and ability to be responsive to the needs of the entire academic geography community, and to undertake collaborative research with scholars outside the Center. The June, 1992 meeting of the Board of Directors approved a modified plan for the adoption of new initiatives that includes several new levels of approval and peer review, which will help to strengthen the perception that the activities of the Center are open to participation by the entire community.

1. BACKGROUND

On August 19, 1988, the National Science Foundation (NSF) awarded the NCGIA to a consortium of the University of California, Santa Barbara; the State University of New York at Buffalo; and the University of Maine, with funding of $1.1 million per year for five years. The fourth year's operation began officially on December 1, 1991. The decision to establish the Center and the selection process have been described by Abler (*International Journal of Geographical Information Systems* **1**: 303-326 (1987)).

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

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

In response to continuing trends in the field of geographic information and analysis, and to prepare for an extended process of evaluation by NSF in connection with possible renewal of the Center's cooperative agreement beyond 1993, a strategic planning exercise was conducted in 1991. It led to the adoption of a new mission statement, and new goals and objectives, and these became the basis for a renewal proposal submitted in November, 1991, and covering the period 12/1/93 through 11/30/96. The mission of the National Center for Geographic Information and Analysis is: **the advancement of geographic research of lasting and fundamental significance**. Specifically, we will continue to:

1) Advance the theory, methods, techniques and applications of geographic analysis based on geographic information systems (GIS) in the many disciplines and professions involved in geographic research;

2) Augment the nation's supply of experts in Geographic Information Systems (GIS) and Geographic Information Analysis (GIA) in participating disciplines;

3) Promote the diffusion of analysis based on Geographic Information Systems (GIS) throughout the scientific community and provide a conduit for disseminating information regarding GIS research, teaching, and applications; and

4) Interact with individual researchers and organizations on a national and international basis.

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

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

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

In June, 1992, the Center adopted a new, revised research plan that preserved the research initiative as the primary vehicle for organizing work on the research agenda, but with the addition of new vehicles, a more rigorous process of review of proposed initiatives, and more formal mechanisms for collaboration with individuals or groups outside the Center. The following sections lay out the specific details of the research plan that now guides the research operations of the Center.

1.1. Research Initiatives

The Research Initiative is the major vehicle for focused research at the Center. Research Initiatives provide a mechanism for selecting high priority, focused topics from the Research Agenda, scheduling and staffing them within the resource constraints of the Center, building cooperation with researchers outside the Center and involving them directly in the Center's work, and bringing research to closure in a timely and effective fashion. The Initiative life cycle described below includes several opportunities for external review. It has evolved steadily since the Center's inception through experience, advice from the NCGIA Board of Directors and external consultants, peer and panel reviews solicited by NSF, and informal comments received.

A major goal of the Initiative model is to involve the general research community in prioritizing and pursuing a research agenda both within and outside the Center. As the Center approaches Year 8 and possible termination of NSF core funding, its viability will depend more and more on the existence of an initiative process that is perceived as open, formally structured and rigorous. If the Center is to be truly a National Center, then every GIA researcher in the U.S. should feel that they have a stake in the Center, and an opportunity to participate in its research activities. Experience has taught us that this goal is very hard to reach, but we believe that the process outlined below can help us get closer to it.

1.1.1. Selection of topics for Initiatives

The domain of NCGIA research is defined by the Research Agenda. This is a published document; the 1987/8 version was published as NCGIA (1989), and the 1991 version (included as part of the renewal proposal) was published as NCGIA (1992). While it defines the research topics of interest to the Center, the Research Agenda is also intended to serve as a "strawman" for national and international debate.

Within the parameters of its published Research Agenda, NCGIA invites suggestions for new Research Initiatives and suggestions for prioritization. Responses come from individuals, and also from public agencies interested in promoting or funding research in particular areas. A call for ideas for new Initiatives is published in every issue of the Center newsletter *Update* (approximately every nine months) and in a selection of relevant professional publications at least once each year. Respondents are asked to provide supporting arguments that address:

- the linkages between the proposed Initiative, the NCGIA Research Agenda, and current and past Initiatives;
- the breadth and depth of fundamental scientific questions addressed by the proposed topic;
- the advantages, if any, in tackling the topic as a Center Initiative with a multidisciplinary, multi-investigator team, rather than through conventional, single-PI research;
- whether the topic contains researchable questions on which substantive progress can be made in a two year time frame.

The NCGIA Science Policy Committee considers all suggestions at its regular semi-annual meetings. Three issues are of primary concern to the SPC at this stage:

- whether the topic has sufficient fundamental scientific merit and priority within the Research Agenda;
- whether it merits the Center's style of multidisciplinary, multi-investigator research; and
- whether the Center's personnel and financial resources, including funds raised from external agencies, will be sufficient to mount a credible Initiative on the topic.

If the SPC determines that the topic has merit and warrants further serious consideration, it forwards a short description with supporting arguments addressing the issues identified above to the NCGIA Board of Directors for approval in principle.

A submission for approval in principle must include the following headings:

Research area: A list of sections in the NCGIA Research Agenda relevant to the proposed Initiative.

Leaders: Names of the Initiative Leader and (optionally) co-Leaders. Leaders and co-Leaders must have been selected and confirmed at this stage.

Potential Center participants: Names of potential participants in the Initiative from the three NCGIA sites.

Core planning group: Names of potential members of a core planning group for the Initiative.

Disciplines to be involved: All Center Initiatives are expected to draw from a range of disciplines.

Duration: Tentative dates for the active period of the Initiative.

Objectives: Major scientific objectives of the Initiative.

Fundamental social and scientific questions: A discussion (1 page) of the major social and scientific questions to be addressed by the Initiative.

Research methods and researchable questions: A discussion (1 page) of the methods to be used, and potential topics that can be researched within the active period of the Initiative.

Draft list of potential participants: A list of possible participants at the Initiative Specialist Meeting, emphasizing the range of disciplines, and the need to involve private and government sectors.

The membership of the Board of Directors is drawn from the academic research community, potential funding agencies, professional societies, and the GIS software and hardware industries. As such, it is able to provide an independent view of the appropriate priorities for the Center, and the suitability of research topics. After approval in principle by the Board, the SPC works with proposers to prepare a detailed proposal for the Initiative. The detailed proposal should address the topics normally discussed in a proposal to NSF, but need not be of the same length (5 pages of research plan is acceptable).

The Board of Directors selects qualified independent reviewers to comment on the merits of the detailed proposal and provide constructive criticism. It is important that the Board draw on as wide a group of scientists as possible in the conduct of this evaluation, and possibly seek advice from NSF, especially when the Board has few members with extensive experience in the type of research that is likely to be undertaken. The Board forwards the comments of the reviewers and the Board's own assessment of the proposed Initiative to the Chair of the Science Policy Committee. Initiatives are assigned numbers following approval in detail.

The original proposer of an initiative which is ultimately approved and implemented by NCGIA will be invited, at the very least, as a member of the Core Planning Group for the Initiative. In addition, opportunities for various forms of support for any external researcher are described in Section 1.4 below.

If a proposal is deemed highly meritorious but Center resources are judged inadequate or the scope of the proposal is judged too narrow to support a full Initiative, the Center strives to offer alternative NCGIA research vehicles which might support the work (*e.g.* administrative or financial support for a visiting research associate, mini-conference, working group, *etc.*) or may assist the investigator in seeking resources from alternative sources in order to accomplish the research.

1.1.2. Specialist Meeting process

A Research Initiative begins with a Specialist Meeting which brings together experts in the field both nationally and internationally to discuss the problem in question. This meeting enables experts to discuss and propose how research in the field might best be initiated, and thus a central output from the meeting is a list and plan of key research directions which the Center would stimulate over the following 18 to 24 months. These Specialist Meetings provide the opportunity for constructive brainstorming, but they also involve the presentation by the experts in question of important ideas which already define the field. The eleven Specialist Meetings held

through 1992, and the published research agendas resulting from them, have been one of the Center's more important contributions to the development of GIS research.

After approval in detail of an Initiative and consideration of budgetary constraints, advertisements for visiting professors, post-doctoral researchers, and graduate students to work with a specific Initiative will typically be published from six months to a year in advance of the predicted date of the Specialist Meeting for the Initiative.

Planning for the Specialist Meeting begins with selection of a Core Planning Group with majority representation from universities and organizations external to the Center. The members are typically nominated by the Initiative co-Leaders in consultation with the SPC. The initial roles of the Core Planning Group are to bound the issues to be addressed by the Initiative (typically through creation of a jointly authored research framework paper which is widely disseminated prior to the Specialist Meeting) and to establish a procedure for selecting participants in the Specialist Meeting process.

The process of selection of participants in Specialist Meetings varies depending on circumstances. All Initiatives issue open calls for expressions of interest in participating in the Initiative. The preferred method is to issue an open call which provides access to the framework paper developed by the Core Planning Group and invites submissions of extended abstracts (2000 words) or full papers for consideration. Participation is then based on refereeing of the extended abstracts or papers by the Core Planning Group.

Experience has shown that selection by refereeing increases the quality of preparation for the Specialist Meeting, increases the commitment of the participants, identifies researchers we otherwise might have overlooked, and increases the quality of the output from the Specialist Meeting. On some research topics, however (particularly in highly technical areas), those who are qualified to speak insightfully and authoritatively on the issues are relatively evident from the published literature on the topic. In those instances, personal contact and persuasion may be a more appropriate means
of gathering together the most productive group of individuals. For other Initiatives, participation based on refereed submissions with several key invited participants is an appropriate method to follow. The method used is determined by the Core Planning Group.

As a condition for participation in a Specialist Meeting, participants are required to submit a position paper on one or more of the key research topics to be addressed by the Initiative. Although not always possible, we prefer that Initiative Leaders require submission of completed papers an adequate time in advance of the Specialist Meeting in order to allow them to be anonymously reviewed prior to the meeting. Refereeing helps ensure that every paper has been read in depth by at least several other participants prior to the meeting. Because their perspectives have already been reviewed by others, participants are then able to spend more time discussing substantive research issues. Experience has shown that participants are willing to put the extra effort into producing a quality paper on time if the co-Leaders promise to pursue a book contract for the papers, or a special edition of a journal, or provide some similar incentive.

All Specialist Meetings require the participants to arrive at a recommended research agenda for the general research community on the topics addressed by the Initiative. We have used many methods in Specialist Meetings for accomplishing this but often a process of alternating small focus groups with plenary sessions moving from fundamental questions to specific research topics is used.

Within 6 months of the Specialist Meeting, the Specialist Meeting report is published in the NCGIA Technical Report Series and contains the recommended research agenda arrived at by the specialists. Also within 6 months after the Specialist Meeting, NCGIA researchers report on those specific research plans they will be pursuing which have been derived from priority topical areas or priority fundamental questions identified during the Initiative meeting process. These tentative plans for the involved NCGIA researchers may be published in the Specialist Meeting report or placed in the next semi-annual summary report made to the Board. The fact that an NCGIA researcher or team of researchers is focusing on a specific fundamental research question should not in any way preclude others from seeking funding on the same or similar questions and NCGIA work should perhaps be cited in such proposals as an indication of the importance of the research questions involved.

1.1.3. Active research phase

Following the Specialist Meeting, research activities within the Center maintain momentum in several ways: through structured research by graduate students and faculty; by proposals for in-depth research to be funded by agencies and institutions usually other than NSF, and often involving cooperation with researchers outside the consortium; and through the organization of workshops, working groups and conferences.

The active research phase commences with the conclusion of the Specialist Meeting and terminates two to three years later upon completion and approval of the Closing Report for the Initiative. During this phase, detailed research plans extending from priority questions identified through the Initiative process are developed and pursued by those both internal and external to the Center. Opportunities for external participation in the active research phase include:

- direct funding of visiting researchers for periods from one week to a year;
- accommodation for visiting researchers for similar periods;
- joint collaborative research proposals by external participants and NCGIA researchers to external funding agencies in which NCGIA provides contributory support;
- funding of direct costs of research in which NCGIA retains substantial control over the quality and content of the work through a close supervisory or cooperative relationship.

Further comments on external cooperation appear in Section 1.4 below.

During the active phase, progress on the Initiative is formally reported by the co-Leaders to the Board at each if its semi-annual meetings. In this regular report, the co-Leaders are required to describe:

1. Review of goals and objectives of the Initiative
2. Date of Specialist Meeting
3. Major events in the Initiative since the last Board meeting
4. Summary of intellectual or scientific progress under the Initiative over the previous six months
5. Research activities in the previous six months
6. Discussion of any problems, concerns, or issues affecting the Initiative
7. Major events contemplated for the next 8-12 months
8. Plans for completing the Initiative, including details of events and dates.

A review of the current agenda and progress of each active Initiative is made by the Board at each of its meetings, based on the submitted reports and discussion with Initiative Leaders, and the Board is asked to approve the progress and plans of each active Initiative. Regular updates on the progress of Initiative work are made known to the external research community through the semi-annual NCGIA newsletter. A formal annual report itemizing research progress must also be submitted to NSF each year as part of the incremental funding process.

Significant funding of the active research phase typically continues for about two years. Funding continues until one or more of the following conditions is met:

- work plans developed at the Specialist Meeting and addressing the fundamental questions within the scope of the Initiative have been completed;
- substantive progress has been made (or topics have been exhausted) and the need arises from a managerial perspective to begin other Research Initiatives;
- results have made it clear that a substantial revision of the Initiative’s research agenda is called for.

At that point primary funding is moved to support of other Initiatives. However, depending on the nature of the research, a significant period of time may yet be needed to write up and publish research results. Thus, although primary funding of the Initiative may have ceased, the active phase is not concluded until findings of the research have been reported in a recognized national or international forum. From practical experience, this lag period typically adds a year to the active phase.

The reporting of research results is accomplished in the active phase primarily through refereed journal articles, refereed conference proceedings and chapters in books. NCGIA researchers are present at most major conferences relating to GIS/GIA research and participate in research presentations, panel discussions and debates at those conferences.

The work of the Initiative is officially completed with submission and approval of a formal Closing Report to the NCGIA Board of Directors. The substantive results and scientific progress of the Initiative are documented in this report by addressing the following questions:

- How is the research agenda different from when the Research Initiative started?
- What do we now know that is new?
- What recommendations does NCGIA have regarding fundamental questions in the areas addressed by the Initiative?
- What has NCGIA learned about the Initiative process and how might the operation of future Initiatives be improved?
- What contribution has the Initiative made to GIS education?

The Closing Report also documents all tangible products generated from the Initiative. The Board has the option of soliciting external reviews of the Closing Report upon its submission and prior to its acceptance. Upon acceptance by the Board, the Closing Report is published and made widely available through the NCGIA publications series.

1.1.4. Outgrowth phase

Although funding for any Initiative extends only for a specific period of time and a Closing Report is at some point submitted, the foundations laid and momentum generated by an Initiative typically result in outgrowth work both internal and external to the Center which is not directly funded by the Center. During the outgrowth phase, Initiative Leaders are encouraged to document and report outgrowth research to the NCGIA Board through the regular semi-annual reporting process.

In summary, the Initiative life cycle is as follows, with approximate milestone dates:

Months	Research Initiative Milestone
0	Proposal received by NCGIA Science Policy Committee (SPC) and forwarded to NCGIA Board of Directors for approval in priniciple.
6	Detailed proposal submitted by SPC to Board for external review.
12	Results of review received, Initiative approved and numbered, Core Planning Group constituted.
14	New Initiative announced, participation invited.
18	Process of selection of participants in Specialist Meeting begins.
24	Specialist Meeting held to determine specific research agenda, active research period begins.

48 Active research period ends with presentations at a national or international meeting.

54 Submission of Closing Report to Board of Directors, beginning of outgrowth phase.

Although we are generally pleased with the Initiative process, it has become apparent that other vehicles are needed. In some cases, there is a need for initial research to explore the feasibility of an Initiative on a potential topic. Research topics that 'spin-off' from a Research Initiative may involve long-term single-investigator projects of greater depth and specificity. Outgrowth research was anticipated in the original proposal as a natural product of the Initiative model. The research vision should also be expanded to accommodate research themes whose impact would be felt in more than one Initiative.

The National Center has adopted two research vehicles in addition to the Initiative model:

1.2. Other Research Vehicles

1.2.1. Conferences and Working Groups

The NCGIA conference series is designed to encourage involvement of disciplines whose research efforts might benefit from adoption of GIS methods and technology. Those efforts might be quite broadly based, for example to recognize ways in which adoption of GIS methods have advanced and could advance basic social science research. The March 1991 conference 'GIS and the Social Sciences' held in Santa Barbara and organized by Ross MacKinnon provides an example of this type of activity. The 'First International Conference/Workshop on Integrating GIS and Environmental Modeling' was cosponsored by NCGIA and a group of federal agencies in September 1991, and was designed to explore the issues involved in supporting the development and application of environmental models with GIS technology. The program included overview and case study presentations from each substantive area of environmental process modeling, as well as integrated models, and was attended by over 600 people. A conference on 'The Anthropology of Human Behavior through Geographic Information and Analysis' was sponsored by NCGIA and the UCSB Department of Anthropology in February 1992, and an NCGIA-sponsored conference 'Spatial and Contextual Models of Political Behavior' was held in Buffalo in October 1992. Conferences also keep Center members in touch with GIA/GIS research activities in a wide range of disciplines.

Working groups focus on topics that are smaller in scope than Initiatives, and that may benefit from short term (1-2 week) intensive interaction among a small number of researchers. A working group may provide an opportunity for dissemination or transfer of a GIA/GIS concept, method, or technology to the wider community (*e.g.* the 'Rule Base for Map Generalization' Symposium funded jointly by NCGIA and Syracuse University in April 1990). Topics discussed during conferences and working groups may later lead to Research Initiatives.

1.2.2. Research Investigations

A Research Investigation is a research project conducted by one or perhaps two Center researchers over a shorter period of time than a Research Initiative, and requiring a much lower level of investment of Center resources. An Investigation may arise as an outgrowth of an existing Initiative, or as a transition between current and future Initiatives. A project spin-off from the Multiple Representations (I3) Initiative focuses on a multi-scale inventory of existing topographic map series. The goal is to generate a knowledge base of cartographic principles, and to prototype rules for map design and generalization. This Investigation provides a transition between I3 and I8 ('Formalizing Cartographic Knowledge'), and secured external researcher participation (J.-C. Muller of ITC in the Netherlands).

An Investigation may alternatively explore a topic to demonstrate fundamental science issues for subsequent expansion into a full Initiative. An example of this is Densham's parallel computation and GIS project, which received external funding and involved cooperation with the University of Iowa.

1.3. External Review in the Initiative Life Cycle

If it is to be successful as a National Center, NCGIA must not be perceived as closed to the outside world, or somehow subject to less rigorous review than other activities funded by NSF. The Center's activities are subject to a variety of forms of external review, some general and some linked to specific material:

- Core funding from NSF flows under a Cooperative Agreement with UC Santa Barbara, which requires annual reports, and a new proposal for each year's funding, which is then reviewed by NSF.

- On the request of the National Science Board, NSF undertook a full, external review of the Center's activities after 18 months of operation in early 1990. Independent peer reviews were solicited from about 30 researchers across a wide spectrum of interests.

- The NCGIA Board of Directors performs a general oversight function of all aspects of the Center's operation. The Board meets twice annually, and its members are selected to represent a broad spectrum of GIS/GIA interests. Board members are asked to make recommendations on new members, particularly if certain constituencies are felt to be underrepresented. While the fact that members are appointed by the Center might call the Board's independence into question, its continued critique and direction are essential to the quality of Center management and science. Every Board meeting includes a review of the progress and plans of each active Initiative and a detailed presentation and discussion of one or more selected active Initiatives.

- The process of adoption of an Initiative requires external anonymous peer review, managed by the Board. This review provides a check on the Center's judgment that the Initiative topic warrants priority; that it does indeed contain a sufficiently profound set of scientific questions; that it is better tackled by the Center than by individual, independent researchers; and that the Center has sufficient personnel and financial resources. The process of review and the questions asked are somewhat analogous to NSF's peer review of a conventional research proposal. However external review of proposed NCGIA Initiatives is only part of a continuing process of planning and evolution with multiple opportunities for correction and redirection.

- Detailed planning for a Specialist Meeting is carried out by a Core Planning Group with a majority of members from outside the Center. This provides a useful check on the agenda for the meeting, and on the breadth of recruitment of participants. In addition, the Core Planning Group may elect to manage a process of peer review of proposed presentations as a mechanism for quality control and participant selection.

- The Specialist Meeting provides an opportunity for input from outside the Center on planned activities and prioritization of the research agenda. In essence, the setting of an Initiative's research agenda is a collective enterprise for the entire community, as represented by the Specialist Meeting participants, rather than a closed activity of the Center.

- The Center is committed to peer review as a means of ensuring the quality of its published research. Of the 346 publications of all kinds that emanated from the Center through October, 1991, 140 were subject to peer review prior to publication.

- The Center is committed to active promulgation of its findings in a multidisciplinary setting. Although there is ample opportunity for presentations at GIS/GIA meetings, it is important for Center researchers to seek out alternative and varied settings for presentations where results will have the most significant impact on the Center's various missions.

- The Closing Report of every Initiative is presented to a specially appointed subcommittee of the Board for review, and may be subject to anonymous external review if that is deemed appropriate by the Board.

1.4. Mechanisms for Cooperation with the Wider Community of Scholars

NCGIA uses numerous means of cooperating and collaborating with researchers and scholars external to the Center. Among these are the involvement of large numbers of external researchers in Specialist Meetings, support of post-doctoral researchers and visiting professors to work on research within Initiatives, development of cooperative research proposals evolving from Initiative work, direct funding of non-center researchers on cooperative research in which we are able to maintain substantial control over the quality of the work, and limited support for visiting scholars at the Center
who are pursuing personal educational or outreach objectives rather than research objectives. We will continue to support each of these mechanisms and will expand on them during Years 6 through 8 of the Center. Following are more detailed descriptions of mechanisms for cooperation. Two new formal mechanisms for expanding our ability to involve external researchers, namely "Working Groups" and "Research Investigations," have already been described in Section 1.2 above. Our plans for increasing knowledge exchange with industry, business leaders, and other national laboratories through a Corporate Affiliates Program were described in Section 2.1 of the Outreach Program Plan in the renewal proposal.

The process of defining and developing Research Initiatives which is now in place and will be used for both the remaining years of the Cooperative Agreement (1992-1993) and the three years covered by the renewal proposal (1993-1996) contains many

opportunities for linking the Center's research to the wider community. Opportunities exist for involving scholars and professionals from the inception of an Initiative to its completion and beyond. Consultation with external peers has already been achieved informally before the Initiative is defined, but the development of a Core Planning Group composed of Center and non-Center members to plan the Initiative, select the focus, and determine participants for a Specialist Meeting and related conferences and workshops enables the Center to coordinate and mesh its research program with the work of the wider constituency.

External collaboration is intended throughout the life cycle of an Initiative. In this section we will detail the four mechanisms which make this possible and explain how these collaborations work in practice with reference to existing collaborative research involving Center and non-Center members as well as future possibilities.

1.4.1. Cooperative research proposals evolving from the Initiatives

Within the framework of each Initiative, the Center actively solicits and encourages cooperative research with the outside community. This process begins about 12 months prior to the Specialist Meeting with the announcement of the Initiative. It continues during the Specialist Meeting, when Center and outside researchers meet together to develop a research agenda and to plan specific research activities. It is assisted by the existence of a variety of outreach mechanisms, including electronic mail list servers sponsored by the Center (*e.g*. GIS-L), the Center newsletter *Update*, and specialist newsletters sponsored by Initiatives.

Cooperation takes two forms, informal and formal. Informal collaboration brings Center and outside researchers together to work on a topic of mutual interest within the framework of the Initiative but without additional support provided by the NSF core NCGIA grant or other core funding; formal collaboration involves the active pursuit of additional funds to support joint research. As an example of informal collaboration from I3 (Multiple Representations), Barbara Buttenfield from Buffalo and Jean Claude Muller from ITC Enschede (The Netherlands) developed a variety of projects on line generalization, some funded by the Center through summer salaries and a visiting appointment for Muller. From I6 (Spatial Decision Support Systems), Paul Densham at the Buffalo site and Dale Honeycutt of ESRI developed new approaches to embedding requisite SDSS functions into generic GISs. Densham was funded by the Center, and Honeycutt's activities were funded by ESRI. Numerous examples of this type of cooperation can be found in publications and Initiative reports. We intend to develop such opportunities for collaboration more formally by linking them to the work of the Initiative Core Planning Group, the aims and outputs of the Specialist Meeting, and the continual monitoring function of the Board during the entire life of the Initiative. We also intend to continue to bring these types of collaboration to the attention of the wider research constituency through newsletter, list-server, and *ad hoc* announcements through a variety of research and professional media.

Formal projects resulting from the Research Initiatives are perhaps equally important opportunities to be pursued by Center and outside researchers. We must encourage more of these as the purpose of the Center is to pursue a wider research agenda than its own members can possibly pursue individually or collectively, and to this end the same mechanisms for pursuit of such opportunities as just indicated are used, with the Center providing the infrastructure to enable such opportunities to be developed. From I5 (Very Large Spatial Databases) Terry Smith and colleagues at UC Santa Barbara, the University of Washington and the University of Wisconsin were awarded over $600,000 by the NSF scientific database program for research on the use of object orientation in environmental modeling. From I6 (Spatial Decision Support Systems) Paul Densham and Marc Armstrong (University of Iowa) were awarded an NSF grant on Parallel Processing by three programs at NSF. Such external funding opportunities will be given a much higher profile as the Center matures.

1.4.2. Visiting Research Scholars

We have already developed an active program of Visiting Research Scholars associated with Initiatives at each site. The Center has formally funded some of these visitors through its NSF grant, other external sources and institutional matches, although an increasing number of visitors are willing to visit the Center on their own funding, having been attracted to the Center by its research program and the facilities available at each site. Visitors are accepted principally on the basis of their relationship to an ongoing initiative, although some visitors come to the Center for educational and outreach opportunities (see below). For example, at Santa Barbara, Bob Haining (University of Sheffield) and Guiseppe Arbia (University of Rome) were funded for four months through a grant from the U.S. Geological Survey for I1 (Accuracy of Spatial Databases), while Bill Reiners (University of Wyoming) spent six months at the Center under his own funding. At Buffalo, visits by Jean-Claude Muller (ITC, Netherlands), Britton Harris (University of Pennsylvania) and Geoff Dutton were funded under Initiatives 3, 6 and 7 respectively, while Paul Longley (University of Wales) visited under his own funding. At Maine, Matt McGranaghan (University of Hawaii) and Wolfgang Kainz (University of Vienna) have been funded as Visiting Research Scholars, while Jesper Petersen (Technical University of Denmark) and Joao Paiva (INPE, Brazil) are examples of self-funded visitors.

Beginning in mid-1993, and subject to funding from NSF, opportunities for Visiting Research Scholars will be advertized in two annual competitions, with closing dates of March 31 and September 30. Applicants are expected to link their proposed research directly to the program of Initiatives, and to be in residence at an NCGIA site for a period of two weeks to one year. Applications are reviewed by the proposed host site, and then forwarded *via* the Executive Committee to the Science Policy Committee and the Board of Directors for final approval at a semi-annual meeting.

Each site makes available a number of full-time research appointments such as Postdoctoral Research Associates and Research Faculty appointments. These positions are linked directly to ongoing research of an active Initiative and provide exciting opportunities for persons with an expertise or interest in a particular research area. National searches are conducted to fill these positions with advertisements appearing in major journals, newsletters and on electronic distribution lists. For instance, at the University of Maine, over the course of the first four years of operation, there have been four Postdoctoral Research Associates working on topics directly relating to I2, I4, I5 and I7. At Santa Barbara, Yang Shiren worked as a Postdoctoral Research Associate on research pertaining to Initiatives 1, 5 and 7. Research Faculty appointments provide an opportunity for the Center to have a senior external researcher contribute to an Initiative. For instance, Dr. Renato Barrera was a Research Associate Professor at the University of Maine before leaving to take a position with a leading GIS vendor. Both types of appointments are relatively short-term and provide a means to disseminate Center expertise. Every Postdoctoral Associate supported to date has gone on to an academic position or a similar position elsewhere.

In addition to support of core Center personnel, the NCGIA supports faculty from other Departments on each campus whose research interests complement an active initiative. Support may be in the form of summer salary, graduate students or support of travel costs to appropriate research meetings or conferences. At Santa Barbara, such support has been provided to faculty in the College of Engineering and to several social scientists. At the University of Maine, faculty in the College of Business Administration and the Department of Mathematics regularly receive such support, and at
Buffalo, NCGIA has provided summer support to faculty in the Departments of Industrial Engineering, Computer Science, Linguistics, Anthropology
and Political Science as well as Geography.

1.4.3. Direct funding by the Center of non-Center researchers

We do not believe that the Center should act as a "mini-NSF" by dispensing funds in the form of grants in support of research activities outside the Center. To do so would require substantially more funding than is likely to be available to NCGIA, and would divert substantial resources of personnel into ensuring a program of sufficient scientific rigor and quality. Moreover we feel that the function of funding basic GIS/GIA research belongs to NSF alone, and that the existence of NCGIA should not materially affect an outside investigator's chances of obtaining independent funding from NSF.

At the same time, we believe that it is in the Center's best interests to develop collaborative research with outside researchers, and that this may from time to time require the transfer of NSF funds outside the Center. Such transfers might cover the stipends of graduate student researchers or the summer salary of faculty, or might meet direct research costs, *e.g.* for travel or office expenses. Decisions on such funding are made by the Associate Director at each site, and must satisfy one or more of the following objectives:

- the activity funded is truly collaborative with other activities in the Center, and there are clearly defined deliverables and milestones and a mechanism for quality control;
- the activity is likely to lead to significant external funding;
- the work arises directly from priorities identified through the Initiative Specialist Meeting process.

As an example, the dissertation research of Bijan Azad, a PhD student in Urban Planning at MIT, directly extended work accomplished by Harlan Onsrud and Jeffrey Pinto (Maine) under Initiative 4. His case study expenses were funded by NCGIA. Close supervision was maintained by Onsrud and Pinto by working closely with his faculty advisor (primarily Dr. Lyna Wiggins) and by serving on Mr. Azad's PhD committee. As another example, Dr. Gerard Rushton received direct support in his capacity as co-Leader with Harlan Onsrud of Initiative 9 (Institutions Sharing Geographic Information). Again, because the work is collaborative, NCGIA is able to maintain control over the research activity while avoiding the tenuous position of acting as a "mini-NSF" in funding and passing judgment on the work of external researchers.

1.4.4. Visiting Scholars pursuing educational and professional concerns

Because of the substantial investments in facilities made at each Center site over the past four years, and the presence of a critical mass of active researchers, the sites have become attractive places to visit for scholars wishing to learn about GIS, and to see how it can be applied in their own research. Each site is receiving increasing numbers of expressions of interest from potential visitors, many from other disciplines and from other countries. In effect, NCGIA has become a significant resource for professional development and for the promotion of GIS and geographical analysis.

Each site supports a program of Visiting Scholars with educational and professional objectives. The numbers of scholars accepted under this program is limited by the following set of objectives and constraints:

- unlike the program of Visiting Research Scholars, no support is provided under this program from NCGIA funds for travel, accommodation or living expenses;

- priority is given to Visiting Research Scholars and Center faculty and staff in the allocation of space and computing resources;

- commitment of the time of Center faculty and staff for consultation and instruction is limited to that normally expected to be allocated to students.

Within these constraints, however, the Center will actively assist potential visitors in obtaining appropriate support and accommodation.

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2. SUMMARY OF MAJOR ACTIVITIES

A. Research

Research in the Center takes place within the framework of a series of research initiatives. Each initiative begins with a specialist meeting attended by professionals from outside the Center, in which the most important problems in the subject area of the initiative are identified and ranked and a feasible research agenda for the initiative is defined. Research continues intensively for 24-36 months with teams of faculty (NCGIA or other), postdoctoral fellows, or advanced graduate students, as well as representatives from private industry or government agencies, working in teams on specific problems. Specialist meeting participants and other interested individuals are kept informed of the progress of research through newsletters, symposia, and presentations at conferences. The completion of an initiative is marked by the holding of a national forum to present the research results. Results are also announced in articles in refereed journals, presentations at conferences, bibliographies, algorithms or models for analysis, NCGIA Technical Papers, and short courses or workshops. Completion marks the end of significant financial support from NSF funds, but does not imply that the topic has been exhausted or that the Center's interest in the topic has ended. Rather, completion may signal the need to redefine the research agenda, or to initiate related research in new directions.

During the fourth year two initiatives were begun, and two were completed, leaving a total of six active initiatives at the end of year 4:

4. *Use and Value of Geographic Information*. Co-Leaders: Harlan Onsrud (Maine), Hugh Calkins (Buffalo). Specialist Meeting: Maine, May 1989. Completed with a NATO-sponsored conference in Greece in April, 1992. The closing report will likely be submitted to the Board of Directors for approval at its June 1993 meeting.

5. *Design and Implementation of Large Spatial Databases*. Co-Leaders: Terence R. Smith (Santa Barbara), Andrew U. Frank (Maine). Specialist Meeting: Santa Barbara, July 1989. Completed with presentations at the Fifth International Symposium on Spatial Data Handling, Charleston, SC, August 1992. The closing report will likely be submitted to the Board of Directors for approval at its June 1993 meeting.

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

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

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

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

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

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

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

Initiative 1: Accuracy of Spatial Databases (completed Fall 1990). Presentations on the results of this initiative were made at GIS/LIS 90 in Anaheim, CA. The closing report was approved by the Board of Directors in June, 1992, and published in the Closing Report series.

Initiative 2: Languages of Spatial Relations (completed Fall 1990). Initiative 2 was formally completed in 1990. The closing report for I2 was distributed to SPC members and selected members of the Board of Directors in late April, and approved at the June 1992 Board of Directors Meeting. It has been published in the Closing Report series.

Initiative 3: Multiple Representations (completed Fall 1990). Initiative 3 was formally completed in 1990. The closing report was approved by the Board of Directors at the December 1992 board meeting and has been published in the Closing Report series.

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

The primary wrap-up session for reporting Initiative 4 research results occurred at the NATO Advanced Research Workshop on "Modeling the Use and Diffusion of Geographic Information Technologies" which was held in Sounion, Greece on April 8-11, 1992. Since then, Harlan Onsrud (NCGIA-Maine) and Ian Masser (University of Sheffield) have been working as co-editors on a book containing selected papers presented at the workshop, and summaries of the results of the workshop sessions. The book, "Diffusion and Use of Geographic Information Technologies," will be published by Kluwer Academic Publishers in 1993.

Harlan Onsrud and Jeffrey Pinto (UMaine) have co-authored an article, "Evaluating Correlates of GIS Adoption Success and the Decision Process of GIS Acquisition" which is forthcoming in the *URISA Journal*. This paper reports the results of a theory focused survey by Onsrud and Pinto of local government users of GIS.

Another paper, "Case Study Research Methods for Geographic Information Systems" by Harlan Onsrud, Jeffrey Pinto, and Bijan Azad, was published in the *URISA Journal* in Spring, 1992. The methodologies outlined in this paper were used earlier as the basis for a call to participate in a coordinated GIS case study project at various sites throughout the U.S. jointly sponsored by NCGIA I4 and the URISA Education and Technology Transfer Special Interest Group. Work on several of those case studies by professors and PhD students has continued and initial results of some of the participants were presented at an organized session at the URISA conference in July 1992. A compilation of the case study working papers will be published in the NCGIA Technical Papers Series in early 1993.

Bijan Azad, PhD student at MIT in Urban & Regional Planning, has continued to work closely with his advisors at MIT and the faculty at Maine (Harlan Onsrud and Jeffrey Pinto) on theory development and testing relative to his GIS implementation research. The research plan and interview protocols were completed and site visits occurred throughout the summer months of 1992. Bijan is actively writing up the case reports for the sites evaluated to date and a draft paper describing his research framework has been prepared for publication. Bijan also presented an update on his research in a session at URISA ’92 on "Innovation and Research in Diffusing GIS."

In addition to preparation of the book and presentation of the case study session at URISA ’92, NCGIA organized an Initiative 4 / URISA Education and Technology Transfer SIG session at the URISA ’92 meeting in Washington, titled "Diffusion of Geographic Information Technologies: Current Knowledge and Future Prospects" (Jeffrey Pinto, Ian Masser, Lyna Wiggins, Hugh Calkins and Harlan Onsrud).

Harlan Onsrud and Steven Frank compiled a bibliography of geographic information citations for conferences and compendiums published in 1991. This bibliography is available as the first in the NCGIA Bibliography Series, or in electronic form by anonymous ftp from Santa Barbara. Compilation of a bibliography for 1992 is currently in progress.

Cooperative research on the diffusion and adoption of GIS continues at the University of Wisconsin and Ohio State University. Ben Niemann and Steve Ventura have been funded by the Institute of Environmental Studies under a state-mandated program to undertake a survey of GIS adoption and use by the counties of Wisconsin. In Ohio, Earl Epstein and John Bossler are initiating a similiar survey, and NCGIA will provide cooperative support for this effort. The project is expected to continue for two years, and will roll into the organizational and institutional research agenda of I9.

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

At Santa Barbara, Terry Smith's NSF-funded project, to investigate the design and implementation of modeling and database languages that support scientific investigations involving complex spatio-temporal objects, continues. The project involves Smith and Jeff Dozier as Principal Investigators at Santa Barbara, and collaborators at the University of Washington and the University of Wisconsin. Smith spent the 1991-2 academic year on sabbatical leave at the University of Washington, the University of Wisconsin, and Brown University. Mike Worboys, a computer scientist from Keele University in the UK, visited Santa Barbara for a month in November 1992 and worked with Terry Smith on the development of logic-based and object-oriented approaches to spatial databases, and on spatial topologies. Research completed earlier by Mike Goodchild and Yang Shiren on the properties of alternative orderings of tiles in geographic space will be published by *Computers and Geosciences*.

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

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

At Santa Barbara, NCGIA has initiated a multi-year project in the area of spatial decision support systems with Hitachi America Ltd. Two Hitachi resident researchers are now working at Santa Barbara and will be in residence for the next eighteen months, and two research assistants are funded by the project, which involves Richard Church, Helen Couclelis, and Mike Goodchild. The project is investigating: 1) optimization of the spatial arrangement of energy production and consumption in urban areas, including fuel cells, heat pumps, and waste treatment plants; and 2) the use of cellular automata and neural networks to model and control urban space-time processes related to energy production and consumption, including urban heat islands and urban growth. Both projects will result in the development of spatial decision support systems for designing "green" cities. A second I6 related project funded by Caltrans (the California State Department of Transportation) will investigate the design and implementation of "navigable" databases for support of spatial decisions on transportation networks, under the direction of Church and Goodchild. David Lanter (Santa Barbara) spent the Fall quarter of 1992 in Lisbon at the Portuguese National Center for GIS, collecting case studies for his lineage analysis.

At Buffalo, work is continuing to develop a SDSS for toxic effects modeling of the Great Lakes. This project is in conjunction with UB's Great Lakes Center, and is funded by EPA.

Paul Densham has been refining his locational analysis package (LADSS), which is being distributed in the NCGIA Software Series. A hypertext shell has been developed for the system and users now interact with a flow-chart depicting feasible paths among the system's capabilities. Paths are represented by arrows among a series of boxes, each of which is a button invoking a program in the system. On-line help is provided as well as a range of data generation and management utilities. The shell has been extended to encompass interaction between the locational analysis package and TransCAD (Caliper Corporation). Yuemin Ding (PhD student) and Paul Densham will be investigating the potential of flow-chart interfaces for model base management systems in SDSS in the coming months.

Densham and Marc Armstrong (Department of Geography, University of Iowa) continue their work on the NSF-funded project to improve human-computer interaction in locational decision making. Yuemin Ding is writing his thesis on the use of parallel processing for shortest path algorithms, hill-shading of digital elevation models (DEM), and the generation of Voronoi tesselations and Thiessen polygons. Ding and Densham have developed several parallel versions of Dijkstra's shortest path algorithm. Using two

approaches to decomposing the algorithm, they have implemented software on a 4 node Transputer array in a Hewlett Packard Vectra i486 host. A paper on this research was published in the Proceedings of the 1992 International Spatial Data Handling Symposium. Other I6 related research was presented at this meeting and is included in the Proceedings.

Paul Densham and Michael Goodchild were joint presenters of a workshop entitled Introduction to Spatial Analysis with GIS at the 1992 URISA Annual Meetings in July in Washington, DC. In September, Densham visited ESRI, Redlands, to extend a previously developed conceptual design for future versions of ARC/INFO's NETWORK module and to work on implementing location-allocation modeling capabilities.

Paul Densham organized a paper session on SDSS at GIS/LIS92. The session was chaired by Marc Armstrong (University of Iowa). At the 1993 AAG meetings in Atlanta, Densham will participate in a session on the achievements of I6 and future directions for SDSS research, and the initiative will likely be closed at that time.

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

The I7 specialist meeting was held June 8-12, 1991, in Castine, Maine. Thirty-five participants attended. *NCGIA Technical Report 91-26* describes the Specialist Meeting and its prioritized research agenda.

At Maine, Kate Beard has completed the organization of the I7 Challenge on "Visualization of Spatial Data Quality." The objective of the challenge is to generate external interest in the problem of visualizing spatial data quality. The challenge is co-sponsored by the U.S. Environmental Protection Agency and the U.S. Department of Agriculture Soil Conservation Service (who are each supplying data sets) and by the American Statistical Association. The challenge was announced on GIS-L and will run for approximately one year. The concluding event will be at GIS/LIS '93 in Minneapolis in November.

In July, Barbara Buttenfield and Michael Goodchild attended a conference on "Visualization for GIS" at Loughborough University in the UK, and presented papers on I7 research. A book, *Visualization for GIS*, based on the conference papers, will be edited by David Unwin and Hilary Hearnshaw, and published by Belhaven Press in 1993. The book devotes a full section to Issues of Data Quality and Data Validity, including contributions from Buttenfield and Beard, "Graphical and Geographical Components of Data Quality", and Goodchild, Lin, and Leung, "Visualizing Fuzzy Maps." This latter paper was also presented at the Fifth International Symposium on Spatial Data Handling in Charleston, SC, in August, as was Peter Fisher's "Real-Time Randomization for the Visualization of Uncertain Spatial Information", and Geoffrey Dutton's "Handling Positional Uncertainty in Spatial Databases."

Two paper sessions related to I7 research were convened at GIS/LIS '92 in November, 1992 in San Jose, CA. Kate Beard and William Mackaness organized one session "Visualization of Spatial Data Quality", while Mason Hewitt (EPA) chaired a second session on quality assurance and quality control for spatial data.

Graduate thesis and dissertation projects continue at all three sites. At Maine, Sarah Clapham completed her Masters thesis work on specifications for visualization of data quality. Scales of measurement were used as the link between the behavior of a quality component and behavior of a visual variable. Algebraic specifications were developed for each scale of measurement. These specifications became the modular building blocks for the quality (positional accuracy, attribute accuracy, and currency) and visual variable (color, shape, and size) specifications. Sarah successfully defended her thesis in September 1992 on "A Formal Approach to the Visualization of Spatial Data Quality." An initial paper was presented at ACSM 1991 in Baltimore and final results were presented at GIS/LIS '92 in San Jose with her presentation, "A Formal Approach to the Visualization of Spatial Data Quality".

At Santa Barbara, Diane Schweizer completed her Master's thesis research, "Visualizing Data Quality for Choropleth Maps." At Buffalo, Victor Wu continues work on domain-dependence and object orientation of data quality information. In September, he defended his dissertation proposal "Exploring the Quality of Spatial Data in GIS: Queries Based on Data Objects." He and Barbara Buttenfield interviewed Soil Conservation Service employees at the New York State offices in Syracuse to identify the types and amount of data quality information needed by federal agency users. Also at Buffalo, Chris Weber's dissertation research will focus on hypermedia tools, using aural (sound-based) techniques to represent information on error propagation in spatial modeling tasks. Buttenfield and Weber have authored an invited book chapter on "Multimedia and Visualization in GIS", for the book *Human Factors*

in Geographic Information Systems, edited by Hilary Hearnshaw and David Medyckyj-Scott.

Kate Beard, Michael Goodchild, and David Mark attended a special session on visualization and GIS at the Interface ’92: Graphics and Visualization conference co-sponsored by IEEE and by the American Statistical Association in March, 1992. The purpose of the conference was to encourage interaction between statisticians and other disciplines with research interest in developing tools for visualization. Papers presented included "Spatial, Statistical and Graphical Dimensions of Data Quality" (Beard, Buttenfield) and "Visualizing the uncertainty in multinomial fields" (Goodchild).

Geoffrey Dutton spent a month in residence at Buffalo in February, collaborating with Barbara Buttenfield on a project to adapt visual techniques to monitor error propagation during transformation of digital cartographic data between coordinate systems at differing levels of resolution. Buttenfield and Dutton are completing a paper reporting their collaborative research on resolution-dependent variation in positional accuracy of coordinates undergoing transformations. They have a co-authored paper accepted for the ICA meetings in Cologne in May 1993.

William Mackaness attended a 2 day workshop, "Envisioning Information," at the Eastman Kodak Co. Center for Creative Imaging, Camden, ME. The workshop was hosted by Edward Tufte, and centered around topics such as animation modeling (looking at storm development), and linking and manipulating multivariate data.

Kate Beard, Sarah Clapham, and William Mackaness attended a workshop on Automated Visualization at the Visualization ’92 conference in Boston in October 1992. Barbara Buttenfield is serving as guest editor for a special I7 issue of *Cartographica* on Visualizing the Quality of Spatial Data, to include six peer reviewed manuscripts. The issue should appear in early 1993, and will include a paper by Kate Beard and William Mackaness describing components of spatial data quality and three levels of access (notification, qualification, and quantification) to these components, together with visualization techniques which could provide access to data quality information at these various levels. Beard has also been working on reference grids as a specific visual technique for displaying geometric changes generated by GIS processes. The reference grid is a mesh of uniform cells which is registered and displayed as a backdrop to the data. To date, reference grids have been developed and evaluated for coordinate transformation and edge matching.

At Maine, Kate Beard and William Mackaness conducted a graduate course on Data Quality Visualization for the Fall ’92 semester. The course objective was to examine data quality components and visualization techniques and develop visualization methods for specific quality components.

At Santa Barbara, research continues on the roles of alternative visualizations of error models, with three options easily defined: displays can omit any reference to quality, for example by displaying maximum likelihood classes; displays can include descriptions of data quality in the form of error model parameters; or displays can present a sample of realizations of the error model. The last option is clearly more dramatic, and in the spatial context may be much more intelligible to non-statistical users. Techniques have been developed for displaying realizations under the error model developed by Michael Goodchild and others for Initiative 1. Some preliminary results will be published in the forthcoming book *Visualization for GIS*.

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

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

I8 will build on results from I3 (map generalization and issues of scale and resolution) and I7 (visualization issues), and also will draw on (and contribute to) I13 (interface for the prototype) and I6 (use of graphics for spatial decision support). The initiative will focus on non-thematic maps, which are the most standardized products in terms of data content, quality, and presentation. The goal of the initiative is development of a test-bed for the formalized knowledge, rather than development of a single expert system to

make maps.

Although the initiative has not begun formally, activities in preparation for the initiative are well under way. The Scientific Policy Committee has approved a proposal for the active phase of the initiative to begin in Fall 1993. Due to other commitments, David Mark stepped down as initiative co-leader in late July. Barbara Buttenfield continues to lead the initiative with the assistance of a steering committee, composed of Kate Beard (Maine), Peter Fisher (University of Leicester), Roberta Lenczowski (Defense Mapping Agency), David Mark (Buffalo), Robert McMaster (University of Minnesota), Jean-Claude Muller (ITC), and Rob Weibel (University of Zurich). Peter Fisher visited the Buffalo site in July 1992 to discuss upcoming plans for I8 with Barbara Buttenfield and David Mark. The members of the steering committee met at the ICA meetings in Washington in August. The Specialist Meeting will likely be in October or November 1993 in Buffalo, and will include invited participants from the public and private sectors, and universities.

Research activities continue to progress. Barbara Buttenfield and doctoral student Feibing Zhan have submitted journal articles reporting work on rules for raster generalization of cartographic lines and on an Expert System shell for selection of thematic map symbols. Sven Arve Saga, from the Norwegian Federal Mapping Service, is in residence at Buffalo for the 1992-93 academic year. Saga is working on a dissertation in the Department of Surveying and Mapping, University of Trondheim. At Buffalo, Saga has worked with Buttenfield to establish usable ranges of resolution for coastline features undergoing simplification, using Federal Mapping Service coastline data.

A NATO proposal for an Advanced Research Workshop on Map Generalization was submitted by Jean-Claude Muller (ITC, The Netherlands) and Barbara Buttenfield. The proposal received very high ratings, but was not funded in the round of competition; it will be re-submitted.

Barbara Buttenfield visited Intergraph Corp. in Huntsville, Alabama, in February to advise on system design for an automatic map generalization module to be implemented in Intergraph's MGE (Modular GIS Environment) product. Also advising at the same meeting were Kate Beard (Maine) and Bob McMaster (University of Minnesota).

The ICA has a working group on Map Generalization, chaired by Rob Weibel. The group met during the ICA meetings in Washington in August to discuss research priorities for the general community. Rob Weibel has distributed a questionnaire to cartographers to solicit information on research related to automation and rule bases for map generalization. Weibel is currently tabulating the results, which should be available soon.

Special paper sessions on Formalizing Cartographic Knowledge have been accepted for the ICA meetings in Cologne, Germany in March 1993.

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

This initiative was organized by a seven member core planning group representing six universities and is led by Harlan Onsrud (University of Maine) and Gerard Rushton (Iowa). The Initiative 9 specialist meeting was held February 26-29, 1992, in San Diego, and focused primarily on behavioral and organizational issues acting as impediments or incentives to the sharing of geographic information among and within organizations. The meeting brought together over thirty participants from three major groups. The first group consisted of individuals from five different user segments who were requested to provide detailed reports describing their geographic data sharing experiences and relate them to the initiative research framework. The second group of individuals were from the organizational theory, management information system (MIS), behavioral theory, and methodologist academic communities while the third group of participants came from the academic and general GIS communities. Participants in the specialist meeting were selected primarily through the refereeing of abstracts submitted in response to an open call for participation. The results of the Specialist Meeting are documented in NCGIA Technical Paper 92-5.

Participants at the Specialist Meeting were asked to suggest subsets of issues they felt were fundamental to the understanding and promotion of geographic data sharing. Focus groups were formed to work on fundamental questions and research topics within the following areas: (1) metadata, (2) infrastructure, (3) legal, economic, and cultural aspects, (4) organizational aspects of sharing geographic data, and (5) methodology and substantive case studies.

Work in the latter part of 1992 concentrated on the production of a book from the papers prepared for the I9 specialist meeting. Complete papers were prepared prior to the specialist meeting by all participants and peer reviewed. The co-leaders, Harlan Onsrud and Gerard Rushton (University of Iowa) read all the papers and peer reviews and informed authors of those revisions which were necessary before their papers would be included in a book proposal to a publisher. Revisions have been made to the papers by the authors and the co-leaders are currently re-reading and editing all the papers.

At GIS/LIS 92 in San Jose in November, Michael Goodchild organized a special ASPRS session on recent developments in quality assurance and quality control. Panelists included Mason Hewitt III (U.S. Environmental Protection Agency), Howard Veregin (Kent State University), and Douglas Nebert (U.S. Geological Survey). The panelists reviewed recent efforts at controlling data quality and communicating information on quality to users as a means of enhancing opportunities for effective data sharing.

Steven Frank (UMaine), working with Harlan Onsrud, has developed a PhD dissertation topic on "Cataloging paradigms for spatial metadata." He recently submitted an article for review and potential publication titled "Finding Spatial Data in the Information Infrastructure."

Gerard Rushton has recently received a research grant (with Marc Armstrong, The University of Iowa) from the Midwest Transportation Research Center to "Develop a Spatial Data Infrastructure for Transportation Planning and Public Policy Analysis."

Following the adoption of the Spatial Data Transfer Standard as Federal Information Processing Standard (FIPS) 173, there has been increasing attention in recent months to the development of standards for metadata, or data about data, that can improve opportunities for sharing by allowing potential users to assess fitness for use. Michael Goodchild gave a keynote presentation at a workshop on metadata organized by the Federal Geographic Data Committee in Washington in June, and has prepared a response to the proposed spatial metadata standard currently being circulated by FGDC. Goodchild and Frank will attend an FGDC-organized meeting on the National Spatial Data Infrastructure in Charleston, SC, in February 1993. In addition both Goodchild and Barbara Buttenfield are NCGIA members of the National Research Council/National Academy of Sciences Mapping Science Committee, which is currently refining the concept of a National Spatial Data Infrastructure.

At Santa Barbara, Robert Barr is visiting as a Harkness Foundation fellow for the 1992/3 academic year, and continuing his research into data sharing, and the effects of data pricing policies and their impact on data sharing. Goodchild chaired the Research and Education Technical Advisory Committee of the California Governor's Geographic Information Task Force, which reported in late 1992 on policies for geographic information in the state.

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

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

- to provide computational frameworks, within which geographic phenomena and their temporal changes can be simulated;
- to formalize human reasoning processes about geographic space; and

- to examine (verify/dismiss/refine) computational reasoning frameworks with observations from experiments about human spatial and temporal perception and cognition.

The Specialist Meeting for Initiative 10 will take place on May 8-11, 1993, at Lake Arrowhead, California with co-leaders Reginald Golledge (Santa Barbara) and Max Egenhofer (Maine) in attendance. Approximately 30 participants will be selected to attend. To focus the attention on temporal issues, we have given the meeting the title, "Time in Geographic Space." This resulted from discussions at the pre-specialist meeting, held in San Miniato earlier in 1992, whose topic was "Spatio-Temporal Reasoning in Geographic Space." Participants at that meeting focused their discussions on research issues in spatial reasoning. The Specialist Meeting is, therefore, aimed toward finding the complementary research questions on temporal reasoning in geographic space.

The Call for Papers/Participation for the specialist meeting was been distributed in November. We distributed the call over e-mail to a large number of people who had previously expressed interest in the initiative and posted the ad on all relevant electronic networks. In addition, 500 printed fliers were mailed to academic institutions and selected individuals who have worked in the area of interest. Participants at the specialist meeting will be selected by the steering committee based on extended abstracts (2,000 words). Extended versions of selected papers will be peer-reviewed after the meeting and published in an edited volume.

Other recent activities include the co-organization of and participation in the International Conference on "Theories and Methods of Spatio-Temporal Reasoning in Geographic Space" in Pisa,
Italy (Co-Chair: Andrew Frank), and the workshop on "Reasoning in Geographic Space and Time" in San Miniato, Italy (Co-chairs: Max Egenhofer and Andrew Frank; initiative co-leader Reg Golledge had to withdraw at the last minute because of illness). See "Conference in Pisa" below for further details.

A special session partly co-sponsored by the AAG, is planned for the 1994 AAAS meetings in San Francisco. This meeting will follow the Specialist Meeting and will represent an opportunity to present specialist meeting papers as they have been revised for publication. Presenters will be drawn
from attendees at the specialist meeting.

At the AAG meeting on April 18-22, 1992 in San Diego, Suchi Gopal (Boston University) and Helen Couclelis (UC Santa Barbara) organized a Special Session on Research Issues in Spatial Reasoning. The session was chaired by David Mark and included presentations by Egenhofer on Modeling Topological Relations between Point-, Line-, and Area-Objects; Frank on Spatial Relations in Experiential Spaces; Gopal on Accuracy Assessment of Thematic Maps: A Knowledge Engineering Approach Using Fuzzy Logic; and Couclelis on a Cognitive-Linguistic View of Map Interpretation.

At the University of Maine, Khaled Al-Taha completed his PhD thesis on "Temporal Reasoning in Cadastral Systems". Max Egenhofer has continued research into the formalization of spatial topological relations with papers presented at the conferences on "Spatial Data Handling" and "Vision Geometry" and five manuscripts submitted to refereed outlets. The initial theory, developed under Initiative 2, is frequently cited in the literature and used by an increasing number of other researchers for further studies. In Max Egenhofer's graduate seminar on "Object-oriented GISs" students are designing and implementing a prototype of spatio-temporal reasoning that integrates qualitative and quantitative spatial and temporal relations.

At Buffalo, May Yuan's PhD topic involves data models for wildfire (forest fires, brush fires, grass fires, *etc.*) in GIS. The dissertation, supervised by David Mark, has a major focus on spatio-temporal representation, especially regarding different spatial and temporal scales needed for different uses of wildfire data. Also at Buffalo, David Mark's advanced seminar in GIS has discussed temporal reasoning, time geography, and time in GIS. Students in the seminar have initiated a project to look at periodic markets as a case of spatio-temporal distribution of human activities.

At UCSB, Reginald Golledge has completed a paper on "Integrating Information Learned in Unfamiliar Environments." A PhD student, Mei-po Kwan, is preparing a dissertation on the use of GIS in modeling household decision-making, and with Golledge and Tommy Gaerling (University of Umea, Sweden), she has submitted two papers on "Using GIS to Build a Computational Process Model of Household Route Choice over Time."

A list server named TGIS-L has been established at Buffalo to provide a forum for discussion of temporal GIS issues. Its formation was initiated at a meeting arranged by Gail Langran (Intergraph) for a group interested in temporal GIS issues, at GIS/LIS '92.

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

Based on presentations made at Santa Barbara by David Landgrebe, Frank Davis and Jeff Star are pursuing a modification of Kerekes's and Landgrebe's simulation model to examine error
contributions from an integrated remote sensing/GIS model of biophysical parameters for a grassland. The datasets and models come from Davis's FIFE work over the past several years. Davis and colleagues propose to extend the Purdue model in several ways, including: (1) a more realistic and data-intensive earth surface reflectance simulator; and (2) a model of grassland evapotranspiration based on the FIFE field measurement system.

Based on Manfred Ehlers' residence at Santa Barbara, Ehlers, Star, and Nick Faust (Georgia Institute of Technology) are developing a proposal for a model of agricultural pollution of groundwater which will examine existing approaches to various components of the groundwater pollution problem with the following purposes:

1) to understand where components are suited to an integrated remote sensing/GIS approach;

2) to posit means to integrate the components into an overall data flow model;

3) to understand the requirements for accuracy and precision in a prediction or simulation model.

In order to accomplish closure on I12, researchers are pursuing several plans:

1) There will be a series of final conference presentations relating to I12 at the 25th International Symposium on Remote Sensing and Global Environmental Change in Graz, Austria, in April 1993. The session will include both invited papers and discussants from within and outside of the initiative research group.

2) A contract for a research monograph for the initiative has been signed with Cambridge University Press. Star and Estes will edit the volume. Authors include Michael Goodchild and Kenneth McGwire (Santa Barbara) on accuracy issues; Terry Smith (Santa Barbara) on large spatial databases; Manfred Ehlers (ITC-Netherlands) on registration; Nick Faust (Georgia Institute of Technology) and Jeff Star on visualization; Gassam Asrar (NASA Goddard) and Jeff Dozier (Santa Barbara) on measurements; John Jensen and David Cowen (University of South Carolina) on mapping; John Townshend (University of Maryland) and Frank Davis (Santa Barbara) on modeling; and Tim Foresman (University of Maryland) on management.

3) A proposal for a monograph on issues of scale in the integration of remote sensing and GIS has been developed by Dale Quattrochi at NASA Marshall Space Flight Center, based in large part on the efforts during I12. This proposal is now under review with potential publishers.

4) Frank Davis (Santa Barbara) and Steve Walsh (University of North Carolina) have negotiated a special issue on GIS and remote sensing integration in models of vegetation for the *Journal of Vegetation Science*. Tentatively, the manuscripts are due in June 1993 and the volume will be published in Spring 1994. Articles for the special issue will include approximately ten papers on methodological issues in GIS, biophysical modeling, predicting species distributions, disturbance and community recovery, and conservation analysis.

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

criteria and methods for the design of user interfaces for geographic software; and to devise and test prototype interface development tools. The prioritized research agenda for Initiative 13, a report on discussions at the specialist meeting, and the 35 specialist meeting position papers, were published as NCGIA Technical Paper 92-3.

A BITNET Listserver called UIGIS-L was established for discussion of issues related to User Interfaces for Geographic Information Systems; by January 1992, UIGIS-L had about 200 subscribers.

At Buffalo, David Mark is working with Martin Helander (Buffalo research scientist from the Department of Civil Engineering) and Pawan Vora (one of Helander's graduate students) on an I13 related proposal to be submitted to the Information Sciences Division of the NSF. There is discussion with CSIRO in Australia about a possible joint conference on User Interfaces. David Mark and Werner Kuhn continue to do research on spatial metaphors for human-computer interaction. Michael Gould's PhD dissertation on human-computer interaction for geographic problem-solving is still in progress, with an early 1993 completion date anticipated. Todd Crane (MA student) is working on a thesis topic of user interface design for a hydrogeological application.

David Medyckyj-Scott and Hilary Hearnshaw, of the Department of Computing Studies at Loughborough, UK, have an I13 related book, *Human Factors in Geographical Information Systems*, in progress. David Mark completed a chapter entitled "Human Spatial Cognition" for that book.

From June 9 to 12, an interdisciplinary workshop on Task Analysis in Human Computer Interaction was held in Schaerding, Austria, and had over thirty participants. A special session on task analysis for GIS was organized, and Werner Kuhn, who had been a member of the program committee, presented a paper on "The role of metaphors in task analysis" and chaired a session on task analysis methods. Additional GIS related papers were presented by Andrew Turk (University of Melbourne, Australia, an I13 Specialist Meeting participant) and Wolf-Fritz Riekert (FAW Ulm, Germany). A book containing some twenty fully refereed papers and discussions of the workshop results will be published in early 1993.

The I13 research agenda was scheduled for presentation by David Mark at the American Congress on Surveying and Mapping's Spring Meeting in Albuquerque, New Mexico, in March, and it will appear in the proceedings of that meeting. David Mark presented the Initiative 13 research agenda at the AAG meeting in San Diego, and also presented a paper on I13 research at the ESRI User Conference in June in Palm Springs. David Mark and Werner Kuhn presented papers on spatial metaphors for human-computer interaction at the Fifth Spatial Data Handling Symposium in Charleston, and are continuing their research on this topic. Four other I13 Specialist Meeting participants also presented papers on user interfaces for GIS at the Charleston meeting: Alan Edmonds, Greg Elmes, Tony Lupien, and Steve Smyth. There were several user interface papers presented at the International Conference "GIS From Space to Territory: Theories and Methods of
Spatio-Temporal Reasoning", in Pisa, Italy, in September.

Max Egenhofer is working with David Mark (SUNY-Buffalo) on cognitive aspects of topological spatial relations. This work spans I2, I10 and I13. Also at Maine, two graduate assistants have been working on different stages of user interface design. Gary Volta completed his Master's thesis on "Interaction with Attribute Data in Geographic Information Systems: A Model for Categorical Coverages" which formalizes the operations a user performs on categorical coverages, and manipulates the attribute space rather than the spatial domain. A paper, co-authored by Andrew Frank and Matt McGranaghan (University of Hawaii) has been submitted for publication. Jim Richards is investigating the visualization of the Map Overlay metaphor at the screen surface. He is building on a model of "data cubes and map templates" previously designed by Andrew Frank.

At the Technical University Vienna, Andrew Frank and Werner Kuhn continue research in the area of GIS user interface design. The two main issues investigated are the role of spatial concepts and of metaphors in the design and use of these interfaces. Werner Kuhn presented a paper on "Paradigms of GIS Use" at the Fifth Spatial Data Handling Symposium in Charleston, SC, in August.

Mark is assisting Tim Nyerges (University of Washington) to prepare a NATO Advanced Research Workshop proposal on Cognitive Task Analysis for GIS. If funded, the workshop would take place in southern Europe in Winter 1994, and would serve as a closing activity for I13. At this time, we expect to formally close the initiative in the last half of 1993. Special sessions at GIS/LIS93, or the 1993 URISA meeting, or both, are being considered.

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

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

The specialist meeting for I14 was held April 15-18, 1992, at Humphrey's Half Moon Inn, San Diego. There were 28 academic participants and 9 participants from the government and private sectors. The technical report on the Specialist Meeting is now available as NCGIA Technical Report 92-11. Stewart Fotheringham and Peter Rogerson have received a book contract from Taylor and Francis to publish a volume of edited papers from the I14 Specialist Meeting. A draft of the book will go to the publisher in late January 1993. A collection of other papers from the Specialist Meeting has been sent out to review for a possible special issue of *Geographical Systems*, with Fotheringham and Rogerson as guest editors.

I14 research at Buffalo includes work being done by Fotheringham, Rogerson, Mike Batty, and Yuemin Ding (PhD student) on the integration of spatial analysis and spatial modeling with GIS. Fotheringham and Ding developed several spatial analysis modules that run on ARC/INFO, such as a module to compute measures of spatial association. They are working on the parallel theme of integrating spatial modeling and GIS. An article about this work appeared in *Computers, Environment, and Urban Systems*. Research is also being carried out on general conceptual issues related to the integration of spatial analysis and GIS (Fotheringham and Rogerson), on updating a general spatial interaction modeling package (SIMODEL), on integrating urban modeling and GIS (Batty), and on the Modifiable Areal Unit Problem (Fotheringham and Densham). Fotheringham and David Wong (Connecticut) are working on further aspects of sensitivity analysis and the zone definition problem, a topic raised several times at the specialist meeting and one that cuts across several research initiatives. Fotheringham, Densham, Wong, and Andrew Curtis (PhD student) are working on the zone definition problem and location analysis, a topic that is also related to I6.

Rogerson and Fotheringham presented the research agenda generated at the specialist meeting in a session at the AAG meeting in San Diego in April. Fotheringham presented I14 work at the IGU meetings in August 1992. Yuemin Ding and Hsueh-Cheng Chou presented an I14 paper at the Fifth International Symposium on Spatial Data Handling, held in Charleston in August 1992, and the paper was published in the proceedings. In September, Fotheringham presented I14 papers at the British RSA meetings in Dundee, Scotland; the Exploratory Spatial Data Analysis and GIS meeting in Amsterdam; and the International Conference on "GIS From Space to Territory: Theories and Methods of Spatio-Temporal Reasoning", in Pisa, Italy. I14 papers were presented at ORSA/TIMS, RSA, and GIS/LIS, all of which had special sessions devoted to spatial analysis. At GIS/LIS, Rogerson presented "A nonparametric test of pattern detection and its use in GIS". UB graduate students Andrew Curtis and Richard Weng presented I14 related papers at the Middle States AAG meeting in Syracuse. There are several sessions on GIS and Spatial Analysis being organized for the AAG meetings in Atlanta in April 1993. There has been significant I14 activity at United Kingdom schools who had representatives at the Specialist Meeting.

Fotheringham and Rogerson co-authored a paper for the *International Journal of Geographical Information Systems* entitled "Problems in spatial analysis from a GIS perspective". This paper was included in the Specialist Meeting volume, and also serves as an overview of the scope of I14 issues. Rogerson has an I14 related chapter scheduled to appear in *The Geographical Analysis of Population*, by Rogerson and D. Plane. Fotheringham has written several commentaries and one paper on the integration of GIS and spatial analysis for *Environment and Planning A*.

Approximately 25 copies of SAM (Spatial Analysis Module) software and a similar number of copies of Luc Anselin's *SpaceStat* have been distributed under the NCGIA Software program.

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

Approval in principle for this initiative was given by the Board of Directors at its December 1992 meeting. A proposal for approval in detail will be submitted for peer review in early 1993.

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

Approval in principle for this initiative was given by the Board of Directors at its December 1992 meeting. A proposal for approval in detail will be submitted for peer review in early 1993.

B. Education

1. General

In education, the major accomplishment of Year Four has been the initiation of the Center's Secondary Education Project, aimed at exploring the role of GIS and GIA in the secondary school curriculum. The following sections review each of the Center's major contributions to education in 1992.

Core Curriculum in GIS: By the end of 1992, well over 1,000 copies of the Core Curriculum had been distributed, and it continued to receive good reviews and comments. A version in Japanese had been prepared and distributed to over 400 sites in Japan. Karen Kemp, formerly Coordinator of Education Programs for NCGIA and now working at the Technical University of Vienna, is participating in the development of a European version of the curriculum under the auspices of the EGIS Foundation. The executive committee of the Education Special Interest Group of the European GIS Foundation has recently distributed a call for proposals from people who are interested in preparing new or revised units for the European supplement, or who are interested in preparing a paper on using the Core Curriculum for presentation at the EGIS conference in Genoa, Italy, in March 1993.

Core Curriculum in Remote Sensing: Planning is under way for a similar project in remote sensing, aimed at providing a source of high quality materials for courses. An announcement of the project will appear in *Photogrammetric Engineering and Remote Sensing* early in 1993. It is being coordinated by a committee which includes Mike Goodchild, Jeff Star, and Jack Estes (Santa Barbara), Tim Foresman (University of Maryland), John Jensen (University of South Carolina), Ron Eastman (Clark University), and others, and with partial sponsorship from Eosat. The project will be broad in scope, with materials targeted at an initial group of three course topics.

Publications: Two papers describing the initial development of the Core Curriculum have now appeared in the *Journal of Geography in Higher Education*. In addition both papers have been reprinted in a special issue of *Cartographica* on GIS education. A paper on the role of the curriculum and GIS in undergraduate education in geography has been published by *The Professional Geographer*, and the *International Journal of Geographical Information Systems* has published an overview paper on NCGIA education activities following the publication of the Core Curriculum. Other shorter articles on the Secondary Education Project have also appeared in journals and magazines, and a paper raising issues in GIS accreditation was published in the *ACSM Bulletin*.

2. Secondary Education Project (SEP)

The focus of NCGIA's education activities has shifted to GIS in the secondary schools. Previous efforts have provided materials and support for GIS education at the collegiate level. Recognizing that the conduit to higher education GIS courses is fundamentally the secondary school, a project has begun that seeks to inquire into the role for GIS in the schools and aid in GIS implementation in that environment. Two impacts GIS may have on the schools have been identified:

1) Presentation of GIS as one of the key technological tools that may help us manage our complex world; further training and education in GIS may enhance employability.

2) GIS in the schools would be an educational aid to the existing school curricula in geography, earth, life, and social sciences; and would promote critical thinking and computer literacy.

In the first year, the NCGIA Secondary Education Project (SEP) has focused on identifying existing GIS activities in the schools, communicating with educators on the place of GIS in the current school setting, and identifying what is required for teachers to incorporate GIS concepts and software in their classrooms. In order to receive early concentrated input from teachers for the SEP, NCGIA hosted a seven day workshop in which ten high school teachers from a variety of disciplines worked with NCGIA researchers to identify the potential for GIS and GIS-aided instruction in the schools. The teachers also helped the NCGIA to identify the materials and support that teachers would need to bring GIS into their classrooms.

In addition to discussion of these topics, the workshop included a short course in GIS, demonstrations of GIS applications, and hands-on use of GIS software. A summary of the workshop will be available as an NCGIA Technical Report in the spring. The teachers' comments were unanimously favorable towards some level of GIS activities in the schools. The teachers pointed out the need for prepackaged GIS activities and low-cost, easy-to-use GIS packages. Although not all the pieces are in place for an easy adaptation of GIS to the secondary school environment, the teachers involved in the workshop attempted some sort of GIS activity in their courses this past Fall.

Based on the experience from this workshop and our other investigations, the NCGIA is planning a second phase with additional workshops for teachers to learn about GIS. Another component will be the creation of GIS modules that would complement existing instructional materials. These modules will be produced in collaboration with experienced curriculum writers, GIS developers, GIS educators, and classroom teachers. The project continues to seek information on GIS activities in the schools, and input on GIS issues at this educational level.

C. Outreach

1. General

The circulation of the Center newsletter *Update* is now approximately 3,500, including over 500 overseas addresses. The newsletter is published approximately every nine months, the latest issue appearing in April 1992. Overview presentations on the work of the Center continue to be made at conferences and stories on the Center appear in magazines, newspapers, and journals. Books have now been published based on the work of Initiatives 1, 2, 3, 5, 10, and 12, and several others are in preparation.

13 new titles were added to the Technical Papers series in 1992. A software series was begun, and five packages are now being distributed. The Closing Reports series now includes reports from Initiatives 1, 2, and 3. Also in 1992 the first edition of the NCGIA Bibliography was published, and this is planned to be a regular annual feature.

In May, Buffalo signed a cooperative agreement for scholarly exchange with the Sharjah Municipality of the United Arab Emirates. This agreement is similar to those the Buffalo site has with the Wales and Southwest Regional Research Laboratories and the National Laboratory of Resources and Environment Information Systems in Beijing. Stewart Fotheringham represented the NCGIA at Sharjah's First Annual GIS and Applications Conference in February 1993.

As a result of the increasing demand for visits to the Buffalo site by people from academic institutions, government agencies, and the private sector, the Buffalo site instituted a program of Visitor Days. The event is scheduled once each month, and brings together a wide range of visitors from outside for an overview of the Center and its research program, and for software and hardware demonstrations in the Geographic Information and Analysis Lab. NCGIA faculty Research Scientists conduct the overview, and graduate students do most of the demos. The program has been very successful so far.

Kate Beard and Sarah Clapham, Research Associate, Department of Forest Management, organized a one day GIS seminar for a group of fifteen people from the Acadia National Park and the Regional Headquarters for the National Park Service, October 13, 1992. Acadia National Park has one of the richest databases in the State of Maine, yet an enormous amount of park information management and decision-making is still performed through manual processes. The seminar began with a morning session providing hands-on tutorials in PC ARC/INFO and IDRISI which capitalized on the available data and presented GIS concepts and applications in contexts relevant to current park management issues, including Conservation Easement Acquisition and Vista Management. The afternoon sessions included a report on a graduate research project supervised by Dr. Steven Sader, UMaine Professor of Forest Resources, on the integration of GIS and remote sensing techniques for the identification of land use / land cover change patterns within and around the park boundaries and a lesson by Louis Morin, Instructor in Forest Resources, on the value of GPS in data collection and update. A lively discussion on implementation strategies for Acadia National Park concluded the workshop. Topic areas ranging from applications development to implementation planning to personnel training and internships were outlined for potential future cooperation between the University of Maine and Acadia National Park.

Maine has been cooperating with personnel from University of Maine's Fogler Library to offer GIS data access capabilities to the general university community through the library system. Arthur Lifshin, Head, Science and Engineering Department, Fogler Library, has received training from ESRI and a grant of ArcView software. Datasets for the State of Maine and appropriate hardware have been acquired by the library. The library is currently training several of its staff on the use of a GIS so that the library will be able to offer students, faculty and the general community the opportunity to access and use spatial data.

I4 and the URISA Education and Technology Transfer Special Interest Group have jointly sponsored a coordinated GIS case study project at various sites throughout the U.S. Work on those case studies by professors and PhD students has been largely completed over the past six months and several of the case studies were presented at an organized session at URISA in July. A compilation of the case study working papers will be published in the NCGIA Technical Papers Series in early 1993.

Cooperative research on the diffusion and adoption of GIS continues with the University of Wisconsin and Ohio State University. In Wisconsin, Ben Niemann and Steve Ventura have been funded by the University of Wisconsin Institute of Environmental Studies to undertake a survey of GIS adoption and use by the counties, under a state-mandated program. In Ohio, Earl Epstein and John Bossler are initiating a similar survey, and a proposal will shortly be submitted to NCGIA for cooperative support of this effort. The project is expected to continue for two years.

2. Conferences

Chinese Professionals in GIS Conference (August 15-16, 1992). Buffalo was one of the sponsors of the first annual Chinese Professionals in GIS (CPGIS) Conference, held at the Center for Tomorrow, State University of New York at Buffalo. There were approximately 120 participants from Australia, Canada, Germany, Netherlands, United Kingdom, United States, and China. About 1/3 of the participants came from China for the meeting. Hui Lin (PhD in Geography, SUNY at Buffalo) acted as Chair for the opening session. Stephen Dunnett, Associate Provost for International Programs, State University of New York at Buffalo, and Michael Batty, Associate Director of NCGIA, gave welcoming addresses. Professor Chen Shupeng of the National Laboratory of Resources and Environment Information Systems gave the keynote address. During the two day meeting, there were 46 paper presentations in 17 technical sessions.

The sponsors for the meeting included: National Laboratory of Resources and Environment Information System (LREIS), Chinese Academy of Sciences, Beijing; NCGIA-Buffalo; National Laboratory of IESMARS; Wuhan Technical University of Surveying & Mapping, Wuhan, China; Council of International Studies and Programs, SUNY at Buffalo; Great Lakes Program, SUNY at Buffalo; Environmental Systems Research Institute; ERDAS; IDRISI, Graduate School of Geography, Clark University; Graduate Student Association, SUNY at Buffalo; Chinese Student and Scholar Association, SUNY at Buffalo; Chinese Graduate Student Association, SUNY at Buffalo; Multidisciplinary Discussion Group of GSA, SUNY at Buffalo; Geography Graduate Student Association, SUNY at Buffalo.

Spatial and Contextual Models of Political Behavior (October 23-25, 1992). Buffalo sponsored a conference on Spatial and Contextual Models of Political Behavior, held at UB. Munroe Eagles, NCGIA Research Scientist from UB's Department of Political Science, was the primary organizer for the conference. The meeting brought together approximately 35 invited scholars (21 from outside UB) from the disciplines of Political Science, Geography, Sociology, and Urban and Public Affairs, to consider issues involving modeling and empirically investigating the spatial dimension of political attitudes and behavior, with a view towards how developments in the field of spatial analysis and GIS might be helpful in advancing the research in these areas. A large number of graduate students and other faculty attended the meeting informally.

Conference participants attended an opening session that provided an overview of the NCGIA, GIS and GIA, and then observed numerous related hardware/software demos in the GIAL. Eighteen papers were presented in six panel sessions. A number of the papers will be submitted collectively for review as a special issue of *Political Geography*, to be co-edited by John O'Loughlin (University of Colorado) and Munroe Eagles.

The Anthropology of Human Behavior through Geographic Information and Analysis (Santa Barbara, February 1-2, 1992). Major advances in the use of geographical information systems have been made in both anthropology and archaeology. Nevertheless, there have been relatively few
published discussions of how GIS can be used to approach and solve complex problems in substantive research. Although discussions of the technical aspects of GIS will continue to be of importance, an alternative means of popularizing GIS in anthropology and archaeology is to demonstrate the role of GIS in the context of research. This conference sought to bring together anthropological users of GIS to describe research that was either too difficult or impossible using any other tools. Some 25 papers were presented over two days. The meeting was be sponsored by NCGIA, the UCSB Social Science Computing Facility and the UCSB Department of Anthropology. An edited book containing the papers will be published by Taylor and Francis. In March 1993 a follow-on conference will be organized by Southern Illinois University, Carbondale.

International conference on "Theories and Methods of Spatio-Temporal Reasoning in Geographic Space" (Pisa, Italy, September 21-23, 1992). This conference, planned as a precursor to I10, was immediately followed by a workshop on "Reasoning in Geographic Space and Time" in San Miniato, Italy. Both meetings were co-sponsored by the NCGIA along with the Commission of European Communities, the University of Pisa, and the Italian National Research Council (CNUCE & IEI) among others. Andrew Frank co-chaired both meetings. At the conference, David Mark gave the keynote address. Two other invited presentations were given by Ben Kuipers (University of Texas) and Richard Snodgrass (University of Arizona). Reg Golledge wrote a fourth invited paper, which was presented by Daniel Montello (Santa Barbara). Full papers were peer-reviewed before the conference and the proceedings of the 23 revised papers, accepted for presentation, were available at the conference and were published by Springer-Verlag in the Lecture Notes in Computer Science
series, Volume 639.

The workshop in San Miniato immediately followed the Pisa conference. The 2-day meeting was funded by the Italian National Research Council (CNR). The majority of the workshop participants had also attended the Pisa conference and frequently, the discussions referred to the presentations at the conference. The workshop was a combination of small-group discussions and plenary sessions in which group leaders summarized the major ideas. A report about the discussions and conclusions is under

preparation. Participants discussed primarily aspects of reasoning about geographic space, and they felt that discussion of time-reasoning in geographic space needed to be based on a better understanding of reasoning about geographic space. Max Egenhofer will make a presentation at ACSM/ASPRS '93 in New Orleans on the results from the San Miniato Workshop.

3. Technical Papers published in 1992

The following titles were added to the Technical Papers series in 1992:

92-1 Locational Models, Geographic Information, and Planning Support Systems, by Britton Harris, U. Pennsylvania, and Michael Batty, SUNY-Buffalo, summarizes the needs and requirements for the development of GIS relevant to urban planning and proposes the idea of Planning Support Systems in linking GIS to predictive and prescriptive land use, activity, and transportation models.

92-2 Generalization of the Digital Chart of the World (DCW), by Frank Fico, SUNY-Buffalo, examines DCW features layer-by-layer and presents specific generalization operators that may be applied to generate a smaller scale dataset from the original product. Some operations are demonstrated using ARC/INFO and the results are displayed.

92-3 User Interfaces for Geographic Information Systems: Report on the Initiative 13 Specialist Meeting, edited by David M. Mark, SUNY-Buffalo, and Andrew U. Frank, U. Maine, contains an account of discussions at the Specialist Meeting; the research agenda for the topic; and the position papers circulated at the meeting.

92-4 Intelligent Assistants for Filling Critical Gaps in GIS, by David Lanter, UCSB, analyzes critical gaps in current geographic information systems that impede their use for spatial
decision support, and provides a research agenda adapting expert systems and other technologies to fill these gaps.

92-5 Initiative 9: Report for the Specialist Meeting: Institutions Sharing Geographic Information, compiled and edited by Harlan Onsrud, U. Maine, and Gerard Rushton, SDSU, includes purpose and scope of the Initiative, abstracts of presentations made at the Specialist Meeting, and recommendations for research in sharing geographic information.

92-6 On the Possible Role(s) of a "University Consortium for Geographic Information and Analysis" (UCGIA): by the UCGIA Steering Committee, summarizes extensive discussions of possibilities for a new organization.

92-7 Research Agenda for the NCGIA Renewal 1993-1996, by NCGIA, revised and updated research agenda for geographic information and analysis, including references and linkages to NCGIA research initiatives.

92-8 Initiative-9: Sharing Information in Third World Planning Agencies, by Michael Batty, SUNY-Buffalo, explores the 'information sharing' paradigm which is rapidly emerging in mature organizations where information technology is being heavily used for communications and decision making, emphasizing ways in which the paradigm might be used in GIS in the Third World.

92-9 GIS Videos: An Annotated Bibliography, by Amy Ruggles, UCSB, describes over 120 educational videos on GIS and related subjects, from government agencies, software and hardware vendors, and independent video companies.

92-10 Spatial Data Analysis with GIS: An Introduction to Application in the Social Sciences, by Luc Anselin, UCSB, reviews the linkage between spatial data analysis and GIS with an extensive illustration.

92-11 GIS and Spatial Analysis: Initiative 14 Specialist Meeting Report, compiled by Stewart Fotheringham and Peter Rogerson, SUNY-Buffalo, summarizes the discussion and outlines the research agenda.

92-12 Two Perspectives on Data Quality, by Helen Couclelis, UCSB, and Kate Beard and William Mackaness, U. Maine. The first report discusses the impediments to effective quality control, and proposes a conceptual model to monitor GIS product quality at any state of deriving an application; the second outlines a research agenda based on the identification of impediments to data integrity.

92-13 A Glossary of GIS Terminology, compiled by Dr. G. Padmanabhan and Jeawan Yoon, North Dakota State University, and Mark Leipnik, UCSB, gives a comprehensive alphabetical listing of technical terms and their common meanings, also an alphabetical

list of acronyms related to GIS.

OTHER NCGIA PUBLICATIONS:

Research Initiative 1: Accuracy of Spatial Databases Closing Report, by Michael F. Goodchild, UCSB, assesses the results of I1 by NCGIA's five closure criteria: what was learned, how I1 has influenced the NCGIA research agenda, how I1 has affected GIS education, what policy considerations emerge from I1, and what were the strengths and weaknesses of the research process?

Research Initiative 2: Languages of Spatial Relations Closing Report, by David M. Mark, SUNY-Buffalo, assesses the results of I2 by NCGIA's five closure criteria (above).

Annual GIS Bibliography for 1991, compiled by Harlan J. Onsrud and Steven Frank, U. Maine.

Annual Report Year 3 (December 1, 1990 - November 30, 1991.

NCGIA SOFTWARE:

S-92-1 SPACESTAT, developed by Luc Anselin, UCSB, covers a range of descriptive spatial statistics, measurements of spatial autocorrelation and tools to implement spatial analysis in regression models. The program interfaces with a number of commercial GIS, including ARC/INFO, IDRISI, OSU-MAP, and generic raster files. It requires an IBM PC compatible with a 80386 or 80486 CPU, math coprocessor, 4 MB of RAM.

S-92-2 GEOLINEUS, developed by David Lanter, UCSB, assists ARC/INFO users on the SUN4 and SPARCstation workstations in lineage tracking, data management, and graphic interface for GIS. (Available through NCGIA to academics only.)

S-92-3 LADSS, developed by Paul Densham, SUNY-Buffalo, a Locational Analysis Decision Support System, requires a PC or compatible with math coprocessor, color video adapter, hard disk and 640 Kb of RAM. (An 80386 or better is recommended).

S-92-4 SAM, developed by Yuemin Ding and Stewart Fotheringham, SUNY-Buffalo, is a Spatial Analysis Module in cartridge form running on the UNIX operating system. It consists of AML and C programs and is run entirely within ARC/INFO.

S-92-5 DIRIGO, developed by Manfred Ehlers and students, U. Maine, is a fourth generation, multispectral, digital image processing system designed specifically for remote sensing applications on the Macintosh II computer. It requires a Mac II, 2 MB RAM, 8-bit display monitor, 20 MB (or larger) hard disk; optional laser printer for hardcopy output.

D. Management

Board of Directors. The Board of Directors oversees the reporting of Center activities to NSF, and acts in an advisory role to the other Center committees. Several changes occurred in the membership of the Board of Directors in Year 4. The Board welcomed Dr. John Eddy (Consortium for International Earth Science Information Network), Dr. John McLaughlin (University of New Brunswick), and Jeanne Savage (IBM). Meetings were held in Santa Barbara (December 1991) and Maine (June 1992) and at the end of November 1992 the members of the Board were:

Joel Morrison (US Geological Survey), Chair
Ronald F. Abler (Association of American Geographers)
Lawrence F. Ayers, Jr. (Intergraph Corp)
Jack Dangermond (ESRI)
John Eddy (CIESIN)
Herbert Freeman (Rutgers University)
John B. Garver, Jr. (National Geographic Society)
Roberta Lenczowski (Defense Mapping Agency)
Patrick E. Mantey (University of California, Santa Cruz)
John McLaughlin (University of New Brunswick)
D. David Moyer (University of Wisconsin-Madison and URISA)
Gerard Rushton (University of Iowa)
Jeanne Savage (IBM)
G. William Skinner (University of California-Davis) (Member, National Academy of Sciences)

The period of service of six members - Freeman, Garver, Mantey, Moyer, Rushton, Skinner - was due to end after the December 1992 Board meeting.

Executive Committee. The Executive Committee is made up of the Director and Associate Directors, and the Chair of the Scientific Policy Committee. The Director is responsible for overall management of the Center, and the Associate Directors for management of operations at each site. There were no changes in the membership of the Executive Committee in Year 4; the members were Michael F. Goodchild (Director); Luc Anselin (Associate Director, Santa Barbara); Michael Batty (Associate Director, Buffalo); David Tyler (Associate Director, Maine); and David Mark (Chair, SPC).

Scientific Policy Committee. During the year from December 1, 1991 to November 30, 1992, the Scientific Policy Committee (SPC) held formal meetings in Santa Barbara in December 1991, and in Maine in June 1992. Other informal meetings of committee members also occurred when opportunities arose. David Mark (Buffalo) served as Chair of the SPC throughout the period. In addition to the Executive Committee members, the SPC included Terence Smith (Santa Barbara); Waldo Tobler (Santa Barbara; NCGIA Senior Scientist); John Estes (Santa Barbara); Barbara Buttenfield (Buffalo); and Harlan Onsrud (Maine). Andrew Frank (Maine) was replaced on the SPC by Kate Beard in June.

The December 1991 SPC meeting in Santa Barbara was the first such meeting attended by Board members, with Joel Morrison there in the morning and Gerry Rushton in the afternoon. After general discussions of the proposal to NSF to extend NCGIA to 1996 (which had been submitted to NSF in November 1991), the SPC discussed the active initiatives, and adopted a draft procedure for closing of initiatives at their completion. The SPC also discussed several ideas for future initiative topics that had been suggested to the NCGIA following an electronic posting of a call for initiative ideas, the concept of a UCGIA ("University Consortoum for Geographic Information and Analysis"), and collaboration between NCGIA and the European Science Foundation regarding a GIS/GIA initiative in Europe.

In June of 1992, the SPC met in Orono. Board members attending were Joel Morrison and Larry Ayers. The procedure whereby all Board members get brief written reports on all initiatives,
in standard format and before the Board meeting, was discussed, and further refined, adding deadlines which should make the process work fully by December 1992. The Committee also reviewed Onsrud's Annual GIS Bibliography project. The SPC then discussed reactions to the site visit for the extension and the Center's possible responses to the recommendations of the Site Visit panel and NSF. Mechanisms for reviewing proposed new initiatives before formal approval were discussed, and formal procedures were adopted. These mechanisms, which now govern the actions of SPC, appear in the first section of this report.

Personnel changes. Peter Rogerson is on leave from Buffalo for the 1992-93 academic year as a Fellow at the Center for Advanced Studies in the Behavioral Sciences at Stanford University. Stewart Fotheringham is serving as Acting Chair for the Department of Geography, and David Mark is serving as Acting Associate Chair for the 1992-93 year. Rajan Batta has been appointed as Interim Chair of the Department of Industrial Engineering.

Khaled Al-Taha, former NCGIA graduate assistant at Maine, has accepted a position as Senior Post-doctoral Research Associate at Louisiana State University. Troy Jordan has been appointed Systems and Network Manager with the NCGIA and the Department of Surveying Engineering. Wolfgang Kainz, Assistant Professor, Department of Geography, University of Vienna, was a Visiting Professor with the NCGIA and the Department of Surveying Engineering from February - June 1992. Joao Paiva, an engineer from the Image Processing Division of Brazil's National Institute for Space Research - INPE, was a Visiting Research Associate from January - December 1992. He studied reasoning methods as applied to river networks.

At Santa Barbara, two new faculty members were added by the Department of Geography in 1992, and both are likely to become involved with NCGIA activities. Dan Montello, an environmental psychologist, is interested in spatial cognition, and made a presentation at the Pisa conference. James Proctor is interested in environmental planning. Bill Reiners, an ecologist from the University of Wyoming, was a visiting scholar at NCGIA for the first half of 1992, and Bob Barr, from the University of Manchester, arrived as a visiting scholar in September 1992 for nine months. Other long term visitors include Andrus Meiner, an environmental modeler from Estonia.

Space. At Maine, the remaining office space on the second floor of the Llewellyn N. Edwards Wing has been completed, and graduate students and faculty have moved into the new offices. The space available to NCGIA at Santa Barbara was increased with the acquisition of an office for the Hitachi project.

3. EXTRAMURAL SUPPORT

A. Grants and Contracts Awarded as of 11/30/92

CALIFORNIA DEPARTMENT OF FORESTRY AND FIRE PROTECTION: "Forestland Mapping Accuracy Assessment" (extension); $20,000. PI: Goodchild. July - December 1992.

CALIFORNIA SPACE INSTITUTE: "Improved characterization of radar scattering from coniferous forest using an L-band multipolarization scatterometer"; $24,985, 7/1/92-6/30/93. PI: Davis

CALIFORNIA WATER RESOURCES CENTER: "Droughts with consideration to El Nino effects in California"; $20,000, June 1992 - June 1993. PI: Loaiciga.

CALSPACE: "Study of a global population database"; $13,500. PI: Tobler. July 1992-June 1993.

CALTRANS: "Distributed navigable database design and implementation issues"; $135,000. PIs: Goodchild, Church.

CIESIN: "Migration of scientific information into the decision-making arena"; $196,436. (5/1/92-4/30/93) PI: Estes.

EG&G ENERGY MEASUREMENTS: "Improved integration of remote sensing imagery with geographic information systems"; $47,084. PIs: Lanter, Estes, Scepan.

EPA: "Advanced remote sensing and GIS research cooperative agreement"; $84,967 (10/1/92-12/31/93). PI: Estes.

HAYNES FOUNDATION: "GIS/ethnographic research on the Los Angeles garment industry"; $101,000: $81,000 original grant, $20,000 for employing Korean ethnographer. PI: Applebaum.

HITACHI AMERICA, LTD.: "Cooperative research between Hitachi America Limited and NCGIA"; $120,000. PI: Goodchild, CoPIs: Anselin, Church. July 1992- June 1993.

IBM CORP: "A Spatial Analysis and Decision Support System for Conservation of Biological Diversity"; $1,188,522 (1/1/93 - 12/31/96). PI: Davis. Co-PI: Goodchild.

INTERGRAPH CORPORATION: "Spatial Relations"; $157,625. PIs: Max Egenhofer and Andrew Frank. July 1992 - June 1995.

KEARNEY FOUNDATION: "Stochastic analysis of ground water flow in heterogeneous formation"; $60,000. PI: Hugo Loaiciga. 1992-1994.

MAPTECH: "Notice to mariners updating problem"; $12,685. PI: Goodchild.

NASA: "Using remote sensing to evaluate a socio-economic and ecological model of land use change" (with ORNL); $99,494 (10/1/91-9/30/93). PI: Estes.

NASA: "Remote sensing information science research" and "improved information science research support and coordination for global science in the EOS Era"; $153,174. PI: Estes (5/1/92-4/30/93).

NASA: "Support of the WETNET program"; $74,996 (renewal). PI: Estes.

NATIONAL AEROSPACE AGENCY: "Scale dependence of area-integrated fluxes over the FIFE site"; $85,000, 7/1/92 - 6/30/93. PI: Davis. Co-PIs: Schimel (Colorado State University), Michaelsen, Friedl.

NATIONAL SCIENCE FOUNDATION: "Toward a system that supports conceptual modeling in data intensive scientific investigation"; $610,808, 9/15/91-8/31/94. PIs: Smith, Dozier.

NATIONAL SCIENCE FOUNDATION: "Spatial properties of configurational knowledge"; $75,735 (3/15/92-2/28/93). PI: Golledge.

NATIONAL SCIENCE FOUNDATION: "Reasoning and interference in spatial knowledge acquisition: the cognitive map as an internalized GIS"; $115,525 (8/15/92-7/31/94). PI: Golledge.

NORTH AMERICAN TREATY ORGANIZATION (NATO): Advanced Research Workshop on "Modeling Diffusion and Use of Geographic Information Technologies"; $31,900. PIs: Ian Masser and Harlan Onsrud.

ROCKEFELLER FOUNDATION: "Integrating GIS and spatial analysis techniques for the study of cassava based cropping systems in Africa"; $66,000. PI: Anselin, Co-PI: Goodchild. April 1992 - April 1994.

SOUTHERN CALIFORNIA EDISON: "Application of an intelligent assistant to analyze geographic information systems use at Southern California Edison's GIS Lab"; $14,000. PI: Lanter

TELESPAZIO: "Survey of Applied Remote Sensing Technology in US"; $35,028. PI: Estes. June 30-December 29, 1992.

UC IRVINE: "A GIS based computation process model of travel destinations in activity scheduling"; $45,056 (7/8/92-7/31/93). PI: Golledge.

UC IRVINE: "Activity based models of accessibility: planning implications for urban subcenters"; $28,475 (8/1/91-4/30/93). PI: Golledge.

U.S. FORESTRY SERVICE: "Spatial decision support systems for the forest plan implementation and update"; $80,959. PI: Church.

B. Equipment and Software Grants Awarded as of 11/30/92

FRANZ INC: Unrestricted donation of software; $66,000. PI: Lanter.

NATIONAL SCIENCE FOUNDATION: "GIS Image Processing Lab"; $56,662. PIs: Kate Beard and David Tyler. July 1991 - December 1993.

SUN MICROSYSTEMS, INC.: "Proposal to Expand the Electronic Research and Instructional Facility at the Buffalo Site of the National Center for Geographic Information and Analysis"; Second phase request for 9 workstations, a server upgrade, and associated peripherals. Educational discount price: $80,840. Co-Principal Investigators: H. Calkins, P.J. Densham, and M. Batty.

C. Equipment and Software Acquisitions

Peripherals (Maine)

Stylewriter printer
Mac Asante ethernet cards (2)
1 MB 2 chip for Mac SE/30 (52)
1 MB 8 chip for Mac SE (2)
Cutting Edge 85 meg. external hard drive for Mac SE/30
Lacie 40MB pocket drive
Seagate 130MB hard drive
SCSI cable
Datadesk MAC101E extended keyboard for Mac IIsi
SCSI Ethernet for Powerbook
5 Meg SIMM modules

Peripherals (Buffalo)

Apple Laserwriter IIG printer
1.3 Gigabyte Sun SCSI disk

Software (Maine)

ArcView (20)
DR Dos 6.0
EndNote Plus 1.2

FileMaker Pro
MacLink Plus
MapInfo
Microsoft Word 5.1 (3)
Microsoft Word 5.0 (4)
Microsoft Word for Windows 2.0
Norton Utilities for Macintosh 2.0
Pagemaker 4.2
SuperPaint 3.0
Systat

PCs and Workstations (Maine)

Goldstar VIP 286-16 personal computer
Macintosh LC with Radius pivot display monochrome monitor

PCs and Workstations (Buffalo)

6 Dell 486 machines (230 mb hard drives, 8 mb RAM)

Software, hardware and peripherals (Santa Barbara)

1 Memory Expansion Board for PS/MOD
10 MB-SIMM for PS 2, Model 70 Motherboard
2 Label Writer II, for MAC and PC
10 Carlisle HS 8 mm/112 8 mm Data Tapes
1 NCD 15s X Terminal with "Unix" keyboard, w/license
1 1/4" cart tape of Xremote (IBM RS/6000 binaries)
1 ARC/Info 6.0 Media Package for Sun Sparc (via RSRU)
1 ARC/Info 6.0 Media Package for IBM RS/6000 (50% paid by Department)
1 Upgrade for existing PC ARC/Info to 3.4D+ (free)
1 Manual for ARC/Info 6.0
1 Transaction for Keycodes
2 Prac. Peripherals V.32bis / V.42bix modem
1 adt/rs6000 bracket for installing hard disk into IBM RS/6000
1 MS Word 5.0 Upgrade for Mac
1 StatSci S-PLUS for SRS/6000 academic site license (purchased with IBM $)
2 StatSci S-PLUS user and reference manuals (by IBM)
1 Informix SE for IBM RS/6000 model 520 (by IBM)
1 Informix SQL for IBM RS/6000 model 520 (by IBM)
8 1 Mb SIMM’s for MacIIx and MacIIfx (4 each)
1 "Sam" anti-virus software for Mac
1 Norton anti-virus software for PC systems
1 Wingz IBM RS/6000 (by IBM)
5 Wingz IBM RS/6000 4 user nodes (by IBM)
1 SPARCstation 10: Model 30 w/one SuperSPARC processor, GX 8-bit Accelerated 2-D/3 D color graphics, 19" color monitor, 32 mb memory, 424 mb disk, 1.44 Mb

3.5" floppy for Hitachi America representative’s use.
1 132 SDK for Windows on PS/2 DOS system
1 Apple 20Mb disk drive for Mac SE
5 MAXHS464 mm Maxell tapes
various 8mm and 4mm tapes
"Digital Chart of the World" on CD-ROM in VPF format
new Mac disk drive for casual staff Mac
HP Postscript cartridge for the HP LJ II

APPENDIX 1 - PUBLICATIONS

A. Articles published or formally accepted in refereed journals

Anselin, L. (1992) Space and applied econometrics - introduction. *Regional Science and Urban Economics* 22(3): 307-316.

Anselin, L, and S. Hudak (1992) Spatial econometrics in practice - a review of software options. *Regional Science and Urban Economics* 22(3): 509-536.

Anselin, L. and A. Getis (1992) Spatial statistical analysis and geographic information systems. *Annals of Regional Science* 26(1): 19-33.

Anselin, L., R.F. Dodson and S. Hudak (in press) Linking GIS and spatial data analysis in practice. *Geographical Systems* 1(1).

Armstrong, M.P., and P.J. Densham (1992) Domain decomposition for parallel processing of spatial problems. *Computers, Environment, and Urban Systems* 16(6): 497-513.

Armstrong, M.P., P.J. Densham, P. Lolonis and G. Rushton (in press) Cartographic displays to support locational decision-making. *Cartography and GIS* 19(3): 154-164.

Batty, M. (1991) New technology and planning: reflections on rapid change and the culture of planning in the post-industrial age. *Town Planning Review* 62(3): 269-94.

Batty, M. (1992) Visual economics. *Environment and Planning B* 19: 489-492.

Batty, M. (1992) A random walk along the urban boundary. *Geographical Magazine* 64(5): 34-36.

Batty, M. (1992) Editorial: Mirror worlds: from infrastructure to infostructure. *Environment and Planning B* 19: 121-124.

Batty, M. (1992) Only twelve aspiring world class universities in Britain? *Environment and Planning B* 19: 242-242.

Batty, M. (1992) Physical phenomena. *Geographical Magazine* 64(7): 35-37.

Batty, M. (1992) The fractal nature of geography. *Geographical Magazine* 64(4): 32-36.

Batty, M. and K.S. Kim (1992) Form follows function: reformulating urban density functions. *Urban Studies* 29: 1043-1070.

Beard, M.K. and W. Mackaness (in press) Visual access to spatial data quality. *Cartographica*.

Benwell, G.L. and H.J. Dickinson (1991) Software requirements for Petri nets in the behavioral analysis of spatial information. *New Zealand Surveyor* 33: 64-79.

Buttenfield, B.P. (1992) An analysis of American Cartographic Association (ACA) membership survey responses. *Cartography and GIS* 19(1): 48-51.

Buttenfield, B.P. (1992) Review of Tomlin, C.D., Geographic Information Systems and Cartographic Modeling (Prentice Hall, Englewood Cliffs NJ, 1990). *Cartography and GIS* 19(4): 262-263.

Buyong, T. and W. Kuhn (1992) Local adjustment for measurement-based multipurpose cadastral systems. *Surveying and Land Information Systems* 52(1): 25-33.

Buyong, T., W. Kuhn and A.U. Frank (1991) A conceptual model of measurement-based multipurpose cadastral systems. *Journal of the Urban and Regional Information Systems Association* 3(2): 35-49.

Church, R.L., S.R. Loban, and K. Lombard (1992) An interface for exploring spatial alternatives for a corridor location problem. *Computers and Geosciences* 18(8): 1095-1105.

Church, R.L. and J. Current (in press) Maximal covering tree problems. *Naval Research Logistics Quarterly*.

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

Church, R.L, J. Current and J. Storbeck (in press) A bicriterion maximal covering location formulation which considers the satisfaction of uncovered demand. *Decision Sciences*.

Couclelis, H. (1991) Editorial: There is nothing as theoretical as good practice. *Environment and Planning B* 18(4): 379-384.

Davis, F.W., D.S. Schimel, M. Friedl, R. Dubayah, T.G.F. Kittel, and J. Dozier (1992) Covariance of biophysical data with digital topographic and landuse maps over the FIFE site. *Journal of Geophysical Research* 97(D17): 19009-19021.

Densham, P.J. and G. Rushton (1992) A more efficient heuristic for solving large p-median problems. *Papers in Regional Science* 71(3): 307-329.

Densham, P.J. and G. Rushton (1992) Strategies for solving large location-allocation problems by heuristic methods. *Environment and Planning A* 24: 289-304.

Eagles, D.M. (1992) Sources of variation in working class formation: ecological, sectoral, and socialization influences. *European Journal Of Political Research* 21(3): 225-244.

Eagles, D.M. (1992) The political ecology of campaign contributions in Canada: a constituency-level analysis. *Canadian Journal of Political Science* 25(3): 535-555.

Eagles, D.M. (1992) Review of Joseph Wearing, Strained Relations: Canadian Parties and Voters. *Political Studies* 40(4): 793.

Eagles, D.M. (in press) Review of Alan Whitehorn, Canadian Socialism: Essays on the CCF-NDP. *Political Studies*.

Eagles, D.M. (in press) Review of K.D. Ewing, Money, Politics, and Law: A Study of Campaign Finance Reform in Canada. *Political Studies*.

Eagles, D.M. and S. Erfle (1993) Variations in third/minor party support in England: One-party dominance and community cohesion perspectives. *European Journal of Political Research* 23(1): 91-116.

Eagles, M. (1991) Review of R.J. Johnston, C.J. Pattie, and J.G. Allsopp, A nation dividing: the electoral map of Great Britain. *Political Geography Quarterly* 10(3): 322-324.

Egenhofer, M.J. (1992) Why not SQL! *International Journal of Geographical Information Systems* 6(2): 71-85.

Egenhofer, M.J. and A.U. Frank (1992) Object-oriented modeling for GIS. *Journal of the Urban and Regional Information Systems Association* 4(2): 3-19.

Egenhofer, M. and J. Richards (in press) Exploratory access to geographic data based on the map-overlay metaphor. *Journal of Visual Languages and Computing*.

Fotheringham, A.S. (1991) Review of J. de D. Ortuzar and L. G. Willumsen, Modelling Transport. *Environment and Planning A* 23: 1826-27.

Fotheringham, A.S. and S. Trew (in press) Chain image and store choice modeling: the effects of income and race. *Environment and Planning A*.

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APPENDIX 2 - PRESENTATIONS BY NCGIA PERSONNEL

December 16, 1991: Frank Davis, Michael Goodchild, and Lauretta Burket were participants at California Department of Forestry and Fire Protection Accuracy Task Force Workshop in Santa Barbara.

December 23: David Mark met with Olav Slaymaker, Professor of Geography and a Vice-President for Research at the University of British Columbia, to discuss a possible campus-wide interdisciplinary initiative on GIS at UBC.

December 23, 1991: Luc Anselin gave a demonstration of SPACESTAT, a program for the analysis of spatial data, Department of Social and Economic Geography, Katholieke Universiteit, Leuven.

January 15: Paul Densham and Mike Batty presented an invited seminar, Business Services from the National Center for Geographic Information and Analysis at the University at Buffalo, in the Western New York Technology Development Center's seminar series, Business Concerns for Manufacturing and High-Technology Companies.

January 16: Rajan Batta presented a talk entitled, Hazardous Materials Transportation: A Review, to the Department of Mechanical Engineering Seminar, Indian Institute of Technology, New Delhi, India.

January 21: Harlan Onsrud gave a half-day seminar on "Legal Aspects of GIS," Pennsylvania Society of Land Surveyors, Pennsylvania State University, College Park, PA.

January: Karen Kemp presented "GIS education around the world: The role of the NCGIA Core Curriculum", at the Second International Symposium on Remote Sensing and Space '92, Hat Yai, Thailand.

February: Peter Rogerson presented a paper on Multiregional projection of the elderly population at the Western Regional Science Association meeting in Tahoe, Nevada.

February 3-7: Barbara Buttenfield visited Intergraph Corporation in Huntsville, Alabama, to advise on system design for a map generalization module in their GIS software.

February 5: Paul Densham was the featured speaker at the Department of Geography/NCGIA Colloquium Series. His topic was Model Base Management Systems and GIS Based Modeling.

February 5: Michael Goodchild made a presentation on "Accuracy of spatial databases" to the Department of Geosciences, UC-Riverside.

February 11: Michael Goodchild gave a plenary address: "Technical developments" at GIS '92, Vancouver, BC.

February 21: Mike Batty was the featured speaker at the Department of Geography/NCGIA Colloquium Series. His topic was Visualizing Spatial Structure: Urban Models, Geographic Patterns and Computer Graphics.

February 22: Frank Davis presented "Modeling geographic patterns of species richness at the landscape level." at the SCOPE Workshop on Biodiversity and Ecosystem Function in Mediterranean
California, Occidental College, Los Angeles.

February 25: Frank Davis presented "Gap Analysis of Biodiversity" at the Land Use and Land Cover Forum of USGS, Reston, Virginia.

February 26-29: Hugh Calkins and Mike Batty attended the I9 Specialist Meeting in San Diego from the Buffalo site. Calkins presented a paper entitled "Elements of a Spatial Data Taxonomy", and Batty presented a paper entitled "Sharing Information in Third World Planning Problems". From Maine, Harlan Onsrud and Steve Frank attended. Onsrud gave a presentation on "Role of law in impeding and facilitating the sharing of geographic information."

March 5: Michael Goodchild presented "Geographic information systems" to a conference organized by Mare Amico (Friends of the Sea), Livorno, Italy.

March 5-7: Khaled Al-Taha visited the Center for Mapping and the Geography Department, The Ohio State University, Columbus, OH, and presented "Temporal Reasoning in Cadastral Systems."

March 6: Michael Goodchild presented "Geographic information systems" at the University of Bologna, Italy.

March 6-8: Andrew Frank co-organized a conference, "GIS for Coastal Areas," Livorno, Italy.

March 7-8: William Mackaness attended "Envisioning Information," a two-day course on visualization, Eastman Kodak Co. Center for Creative Imaging, Camden, ME.

March 11-15: David Mark attended a European Science Foundation (ESF) Workshop on Geographical Databases, held in Aix-en-Provence, France, and presented a position paper entitled "The Importance of a Cognitive Science Perspective for the Design of Geographic Databases". Nineteen people from eight European countries participated. Michael Goodchild was the other US-based participant, and NCGIA was also represented by Andrew Frank. The workshop was the first in a series of three to be held in 1992 to develop a proposal to the ESF for a five-year initiative on GIS and related issues.

March 13: Luc Anselin made a presentation: "Regional analysis using geographical information systems: progress and prospects," at the Regional Research Institute, West Virginia University.

March 17: Frank Davis presented "GIS assessment of biodiversity in California" to IBM Research Division, UCSB.

March 20: David Mark participated in a special session entitled Geographic information systems at the IEEE-sponsored Interface 92 meeting in College Station, Texas. The session was organized by Barbara Buttenfield as part of Initiative 7; presentations in the session were by Kate Beard (NCGIA Maine), Michael Goodchild (NCGIA Santa Barbara) and Mark Monmonier (Syracuse University). Mark chaired the session and also served as discussant. Kate Beard presented "Spatial, Statistical and Graphical Dimensions of Data Quality." Michael Goodchild presented "Visualizing the uncertainty in multinomial fields."

March 22: Michael Goodchild presented "Trends in GIS" at IBM, Kingston NY.

March 22-23: Barbara Buttenfield visited the NSF in Washington to serve on a dissertation review panel in the Geography and Regional Science Division.

March 23: Andrew Frank and Werner Kuhn gave a half-day tutorial, "Geographic Databases: The Issues and Some of the Solutions" at the Extending Database Technology Conference, Vienna, Austria. Max Egenhofer was co-author of this tutorial.

March 23-27: Dennis Jelinski attended the ERDAS Image Processing Workshop at the University of Nebraska, Lincoln.

March 26-27: Michael Goodchild presented "Error and uncertainty in spatial data" at the Kansas Geological Survey, Lawrence, and "Research agenda in GIS" to the University of Kansas Department of Geography.

March: Frank Davis was a participant at an Investigators' Workshop for the Sequoia 2000 Project on Large Capacity Object Servers for Global Change Research, Lake Tahoe.

March 31: Frank Davis presented "Gap Analysis of Biodiversity in California" to the Biological Sciences Division of Pacific Gas and Electric Company, San Ramon.

March: Karen Kemp visited the Regional Environmental Center for Central and Eastern Europe, Budapest, and presented a paper on "GIS education needs and the NCGIA Core Curriculum" at EGIS '92, Munich, Germany.

April 5: Richard Appelbaum made a presentation at the Annual Meeting of the Urban and Regional Research section of the International Sociological Association (UCLA).

April 6: Max Egenhofer presented "Geographic Databases: The Issues and Some of the Solutions," at the University of Maine Computer Science Department Colloquia 91-92, Orono, ME.

April 8-11: Harlan Onsrud co-directed a NATO Advanced Research Workshop, "Modeling the Use and Diffusion of Geographic Information Technologies" in Sounion, Greece.

April 8-11: Dennis Jelinski attended the Landscape Ecology Conference in Corvallis, Oregon.

April 11: Richard Appelbaum made a presentation at the Pacific Sociological Association Annual Meeting (Oakland, California).

April 14: Michael Goodchild made a presentation on "GPS as an aid to spatial data quality: the pluses and minuses" at the On Common Ground Conference, Denver.

April 15-18: The Initiative 14 Specialist Meeting was held at Humphrey's Half Moon Inn in San Diego. Attending from Buffalo were Stewart Fotheringham and Peter Rogerson (Co-Leaders), Mike Batty, Paul Densham, and Andrew Curtis. They authored the following papers for the specialist meeting:

Batty: "Urban models in graphic and geographic information system environments"

Densham: "Integrating GIS and spatial modeling: The role of visual interactive modeling in location selection". Densham's paper was one of six selected for presentation to the entire Specialist Meeting.

Ding and Fotheringham: "The integration of spatial analysis and GIS"

Fotheringham and Rogerson: "Problems in spatial analysis from a GIS perspective"

From Santa Barbara, Sheri Hudak, Waldo Tobler, Uwe Deichmann, Rustin Dodson, and Michael Goodchild attended the specialist meeting.

April 18: Richard Appelbaum made a presentation at the Annual Conference on the Political Economy of World Systems (Duke University)

April 19-22: The 86th Annual Meetings of the Association of American Geographers were held in San Diego. Buffalo participation included:

Rajan Batta presented "Routing of hazardous waste materials: A survey of work done at SUNY at Buffalo", in a special session on Spatial Decision Support Systems.

Barbara Buttenfield presented a paper co-authored with Tom Kress: "Hypermedia tools for data quality displays"

Paul Densham organized and chaired two special sessions on spatial decision support systems, and organized and presented at a workshop entitled "Spatial Decision Support Systems: Principles and Applications". Densham's paper presentation was "Model base management of location selection algorithms".

Dennis Jelinski presented "Heterozygoisity, environmental heterogeneity, and growth of Trembling Aspen"

Stewart Fotheringham and Peter Rogerson presented "Report on the NCGIA Initiative on spatial analysis and GIS"

David Mark organized two sessions, and chaired one session. He presented "User interfaces for geographic information systems: A research agenda", and was a panelist on "Representation of geographic information"

Peter Rogerson and Ge Lin presented "The spatial separation of the elderly and their adult children"

Attending the meeting from Maine were Max Egenhofer and Andrew Frank. From Santa Barbara, Luc Anselin chaired a session on the I14 research agenda. Frank Davis presented "Recruitment dynamics of three oak species in southern California", and "Overview and progress report for NCGIA research initiative 12: remote sensing and GIS" (with J. Star and J. E. Estes). Reg Golledge organized a session on "The interface between geography and psychology". Michael Goodchild presented a workshop on Data Analysis and Modeling in GIS Environments (GIS and Spatial Analysis). Karen Kemp organized a panel discussion on GIS laboratory facilities and a workshop on "Laboratories for GIS education: Hardware, software and exercises" with Steve Palladino. Hugo Loaiciga made a presentation on "Droughts in basins of the Western United States."

April 21: Mike Batty, Ezra Zubrow, and Yuemin Ding visited the Theory Center at Cornell University to meet with Paul Schwarz and Kathy Barbieri about the role of GIS in supercomputing. The Buffalo site continues to be in contact with the Cornell staff about this issue, and has formed a supercomputing research group to continue exploring this topic.

April 23: Michael Goodchild made a presentation to League of California Cities, Committee on 21, San Diego.

April: Frank Davis attended a National Park Service Sierra Global Change Workshop, El Portal, Yosemite National Park.

May 1-2: David Tyler, Steve Frank, and Barbara Bicking attended the ACSM-New England Section and The Atlantic Institute's Regional Surveying Engineering Conference on Trends and Issues in Geo-Information Management Systems, Hartford, CT. Tyler

moderated the session "An Introduction to SDI - Spatial Data Infrastructure and the Concept of Data Integrity." Frank presented "The role of integrated surveying and mapping in a spatial data infrastructure: challenges in spatial information management," Max Egenhofer, co-author. Bicking presented "Data integrity: the academic and research perspective," Kate Beard and William Mackaness, authors.

May 11-15: Kate Beard visited Surveying Engineering and Cartography programs in Germany. She discussed development of GIS curriculum and the NCGIA core curriculum with faculty from the Fachhochschule Berlin, the Berlin Technical University, the Free University of Berlin, the Fachhochschule Dresden, the Technical University of Dresden, the Karlsruhe Fachhochschule and the Technical University of Karlsruhe.

May 11-15: Dennis Jelinski attended a workshop on GRASS 4.0, at Rutgers University.

May 12: Michael Goodchild presented a workshop on Data Analysis and Modeling in GIS Environments (GIS and Spatial Analysis) at the Government Technology Conference 92, Sacramento.

May 13-14: Uwe Deichmann attended the conference "Constructing Socioeconomic Databases for Africa" in London, and made a presentation: "GIS and socioeconomic surveys."

May 15-18: Richard Appelbaum made a presentation at the UCLA Center for Pacific Rim Studies Conference, on "The Globalization of the Apparel Industry in the Pacific Rim".

May 29: Kate Beard and William Mackaness visited the Surveying Engineering Department, New Brunswick, Canada, and met with Y.C. Lee to discuss graduate research at the two sites, and issues
relating to I7.

May 30-June 2: Munroe Eagles presented "Money and votes: Campaign spending and parliamentary election outcomes, 1984 and 1988", to the Canadian Political Science Association’s 64th Annual Conference, University of Prince Edward Island, Charlottetown, PEI.

May: Hugo Loaiciga attended the American Geophysical Union meeting, in Montreal, and presented "Recurrence of earthquakes from fluid pressure rise: model and field observations" (with E.A. Keller) and "Effective hydraulic conductivity in stochastically homogeneous aquifers" (with R.B. Leipnik).

June 1-7: David Tyler participated in the NCGIA Site Visit, Santa Barbara, CA.

June 2: Paul Densham presented an invited paper entitled "Current research in GIS and SDSS" for the Department of Geography, University of Cambridge, U.K.

June 4: Douglas Flewelling presented "An Update on the National Center for Geographic Information and Analysis" at the Northeast Regional Conference of the Highway Engineers Exchange Program (HEEP), Worcester, MA.

June: Frank Davis chaired a peer review panel on the EPA Research Plan: "Simulating climate-biosphere interactions under changing climate conditions," in Corvallis, Oregon.

June 7: Michael Goodchild gave the lunchtime presentation, "GIS: Science or profession?", at the American Society of Civil Engineers, 8th Conference on Computing in Civil Engineering, Dallas.

June 8-12: David Mark attended the Twelfth Annual ESRI User Conference in Palm Springs, and presented a paper entitled "Intelligent User Interfaces: Connecting Arc/INFO and SNACTor, a Semantic Network Based System for Planning Actions". Michael Goodchild was a participant in a panel discussion on GIS in higher education. David Lanter gave papers on "Propagating updates by identifying data dependencies in spatial analysis applications" and "User-centered software designs in GIS: Designing icon-based flow charts to reveal the structure of ARC/Info data graphically" (with Rupert Essinger).

June 10-14: Mike Batty represented the NCGIA at the European Science Foundation Workshop on Socio-Economic Applications of Geographical Information Systems, held in Sintra, Portugal. He presented an invited paper, "Geographic information systems in the social and policy sciences".

June 15: Michael Goodchild gave a presentation on "Accuracy of spatial databases" at Bionetics, Kennedy Space Center.

June 16: Mike Batty visited Professor Michael Breheny, Director of the Spatial Information Systems Program at the University of Reading, to discuss the development of the M.Sc. in Spatial Information Systems program and to develop mutual research interests.

June 16-18: Steven Frank attended the U.S. Geological Survey's "Information Exchange Forum on Spatial Metadata" in Washington, DC. Michael Goodchild also attended the meeting from Santa Barbara and gave the keynote address.

June 19: At the NCGIA Board of Directors Meeting in Maine, the following presentations and demonstrations by UMaine graduate students were made on Science Day: Gary Volta - "Formalization of Families of Categorical Coverages"; Steve Frank - "Spatial Data Library Concepts"; Jayant Sharma - "Topological Consistency"; Doug Flewelling - "Using a Chronology to Describe Geologic Cross Sections"; Khaled Al-Taha - "Temporal Cadastral System: A Prototype"; Jim Richards - "A Direct Manipulation User Interface for Map Overlay"; and Todd Rowell - "User Interface Components."

June 30: Hugh Calkins and Rajan Batta represented the NCGIA in a trip to the West Valley Demonstration Project, West Valley, NY, to continue exploration of how UB's Center for Hazardous Waste Management, NCGIA, and School of Engineering can cooperate with West Valley in analyzing waste treatment problems at this former nuclear fuel reprocessing site.

July: Frank Davis was a participant in the "Second Annual Gap Analysis Workshop," for US Fish and Wildlife Service Gap Analysis investigators, in Logan, Utah.

July: Frank Davis gave a paper on "Conservation planning at different scales of investigation: a comparison of two mapping efforts in Southerns California," at the Biodiversity in Managed Landscapes Symposium, Sacramento.

July 10-15: Michael Batty, Hugh Calkins, and Paul Densham attended the URISA meeting. Batty presented a paper co-authored with Yichun Xie, entitled "Urban analysis in a GIS environment: Population density modeling using ARC/INFO". Calkins presented a paper entitled "Methods and experience in modeling use of geographic information". Densham was joint presenter with Michael Goodchild of a workshop entitled "Introduction to Spatial Analysis with GIS". From Maine, Harlan Onsrud, Steven Frank and Jeffrey Pinto attended. Onsrud presented "Citizen Access and Duplication of Publicly Held Geographic Information Data Sets," in a session on Legal, Economic and Policy Issues in Access to Public Information. He also organized three sessions of the Education and Technology Transfer Special Interest Group: Hot Topics in GIS Education; What Can We Learn from GIS Case Study Research?; and Knowledge Gained and Future Work: Research in the Use and Diffusion of Geographic Information Technologies. Pinto chaired the session on What Can We Learn from GIS Case Study Research?, and Frank presented "GIS Case Study: An Investigation of Technology Transfer Theories at the XYZ Paper Company" in this session. Pinto was also a panelist in the third session and presented "Correlating Adoption Factors and Processes with GIS User Satisfaction in U.S. Local Governments."

July 14: Luc Anselin made a presentation on "Integrating spatial data analysis with GIS," at ESRI, Redlands, California.

July: Barbara Buttenfield presented an invited colloquium "The Role of Hypermedia in GIS" to the Geography Department, University of Leicester, UK. She also met with Alan Strachan, head of Midlands Regional Research Laboratory, to discuss formation of a research MOU with the NCGIA.

July 27 - August 2: Michael Batty attended the Spatially-Oriented Referencing Systems Association (SORSA) Annual Symposium and Workshops held at the University of Ottawa, Canada. He served as a discussant for a session, "Tactical Spatial Decision Support Systems".

July 30 - August 1: Max Egenhofer visited Intergraph Corporation, Reston, VA.

August 2-14: Joao Paiva attended the ISPRS XVII Congress, Washington, DC, and presented "Spatial Reasoning About Flow Directions: Towards an Ontology for River Networks," Max Egenhofer and Andrew Frank, co-authors.

August 2-6: Hugo Loaiciga presented "Probability and climatology of droughts in the western United States" at the American Society of Civil Engineers' Water Forum in Baltimore, MD.

August 3-8: David Mark, Feibing Zhan, Hsueh-Cheng Chou, and Yuemin Ding attended the Fifth International Symposium on Spatial Data Handling, in Charleston, South Carolina. Mark served as a member of the Program Committee for this meeting. NCGIA-Buffalo affiliates presented the following:

Mark: "Spatial metaphors for human-computer interaction"

Zhan and Mark: "Object-oriented spatial knowledge representation and processing: Formalization of core classes and relationships"

Ding: "Parallel processing for network analysis: Decomposing shortest path algorithms on MIMD computers"

Chou, Hsueh-Cheng and Yuemin Ding: "Methodology of integrating spatial analysis/modeling and GIS"

From Maine, the meeting was attended by Max Egenhofer, Andrew Frank (member of the program committee), Doug Flewelling, James Richards, Jayant Sharma, Sabine Timpf, Langley Willauer, and Barbara Bicking. Egenhofer and Frank held a half-day tutorial on "Geographic Databases: The Issues and Some of the Solutions." Egenhofer, Frank, and Flewelling presented "Topological Consistency," Egenhofer and Sharma, authors; "Robust Evaluation of Spatial Queries," Renato Barrera, Egenhofer, and Frank, authors; and "Constructing Geological Cross Sections With a Chronology of Geologic Events," Flewelling, Frank, and Egenhofer, authors. From Santa Barbara, Michael Goodchild gave a paper on "Visualization of fuzzy scenes and probability fields", and Karen Kemp made a presentation on GIS and environmental modeling.

August 7: Karen Kemp attended a seminar of the Commission on Education and Training, International Cartographic Association, College Park, MD.

August 10-14: Harlan Onsrud organized a session at the 27th International Geographical Congress (IGC) in Washington, DC, on Spatial Database Legal Issues (chaired by Robert Aangeenbrug), and gave a talk on "Privacy and Spatial Databases" in that session. From Santa Barbara, Helen Couclelis gave a paper on "Visualizing the quality of GIS products". Stewart Fotheringham presented an invited paper entitled "GIS and Spatial Analysis: A Research Agenda", in a special session on GIS and Spatial Analysis. The session was organized by the Commission on Mathematical Models. Karen Kemp also gave a paper on GIS and environmental modeling.

August 11: Michael Goodchild gave a paer on "Error models for spatial data" at the Joint Statistical Meetings, Boston.

August 11-12: Michael Goodchild and Jeff Star gave a short course on GIS at CIESIN, Saginaw, and ICPSR, University of Michigan, Ann Arbor.

August 14-15: The NCGIA-Buffalo was a co-sponsor of the 1st Annual Chinese Professionals in GIS meeting, held on the University at Buffalo campus. Michael Batty delivered one of the opening addresses for the meeting. NCGIA students presenting at the meeting included:

Yichun Xie and Ge Lin, "TIGER system: architecture, applications and the development potential in China"

Feibing Zhan and Wen-Bin Shi, "GIS in higher education: A review and prospects"

Hsueh-cheng Chou and Fuxiang Xia, "Object-oriented approach to integrate GIS and spatial analysis"

Nan Chau Wang, Kou Wen How, Hung Eu Shan, and Hsueh-Cheng Chou, "Developing Chinese GIS-PC ARC/INFO as a case study"

Feibing Zhan, "Knowledge engineering and the generalization of spatial data base"

May Yuan and Hui Lin, "Spatio-temporal modeling of wildfire in geographic information systems"

Yuemin Ding, "Potentialities and problems of parallel geoprocessing"

Hui Lin, Chyan Wu, Yichun Xie, Hsueh-Cheng Chou, and Yuemin Ding also chaired sessions during the meeting. David Mark and Chris Weber attended sessions.

August 19: Michael Goodchild gave a workshop on "GIS and Resource Management," for GIS World, Fort Collins CO.

August 25-28: Luc Anselin gave papers on "Spatial econometrics in practice: a review of software issues" and "Linking GIS and spatial data analysis: implementation issues" at the Thirty Second European Congress of the Regional Science Association International, Louvain-la-neuve, Belgium. He also organized sessions on "New Directions in Spatial Econometrics".

August: Peter Rogerson attended the Conference on Migration in Post-Industrial Society in Los Angeles, and presented a paper co-authored with Richard Weng, entitled "The Spatial Separation of Parents and their Adult Cbildren".

September: Paul Densham visited Environmental Systems Research Institute, Redlands, to extend a previously developed conceptual design for future versions of ARC/INFO's NETWORK module and to work on implementing location-allocation modeling capabilities.

September 9-12: Stewart Fotheringham attended a conference on Exploratory Spatial Data Analysis and GIS at the Free University of Amsterdam, and presented a paper on "GIS and Spatial Analysis: A Report on the Specialist Meeting".

September 14: Khaled Al-Taha presented "Temporal GISs: From a Transportation Perspective," at the Remote Sensing and Image Processing Laboratory, Louisiana State University.

September 15: Steve Palladino presented "Communicating with and about GIS in the secondary schools" at the National Council for Geographic Education Annual Meeting in Santo Domingo, Dominican Republic.

September 16-17: Harlan Onsrud attended the Society of American Archivists meeting, Montreal, Canada, and presented "Law, Public Policy, and a National Spatial Data Infrastructure."

September 16-18: Stewart Fotheringham attended the British Regional Science Association meetings in Dundee, Scotland, and presented a paper on "Exploratory Spatial Data Analysis and GIS".

September 17: William Mackaness attended the IME Presents Geographic Information System seminar, Sebasco, ME, and gave a talk on "Research Topics Critical to the Successful Use of Geographic Information Systems: A University of Maine Perspective."

September 21: Michael Goodchild gave a workshop on Spatial Analysis and GIS, US Bureau of the Census, Alexandria, Virginia.

September 21-25: Stewart Fotheringham and David Mark attended the International Conference on GIS From Space to Territory: Theories and Methods of Spatio-Temporal Reasoning, in Pisa, Italy. Mark presented the keynote address at the conference, and an additional paper entitled "Counter-Intuitive Geographic Facts: Clues for Spatial Reasoning at Geographic Scales". Mark had earlier served as a member of the Scientific Committee for the meeting. Fotheringham presented a paper co-authored with Andrew Curtis, entitled "Encoding Spatial Information: The Evidence for Hierarchical Processing". Mark stayed in Italy for the I10 related international workshop on Reasoning in Geographic Space and Time, held in San Miniato. From Maine, Max Egenhofer, Doug Flewelling, and Sabine Timpf attended. Egenhofer presented "Reasoning About Gradual Changes of Topological Relationships," Khaled Al-Taha, co-author. Timpf presented "A Conceptual Model of Wayfinding Using Multiple Levels of Abstraction," Gary Volta, David Pollock, and Egenhofer, co-authors. From Santa Barbara, the conference was attended by Helen Couclelis and Daniel Montello.

September 24-26: Paul Densham attended the 4th International Conference on Applied Demography in Bowling Green, Ohio, and presented a paper entitled "Interactive Locational Analysis of Small-Area Demographic Data in Spatial Decision Support Systems", in a special session on the use of GIS in Spatial Decision Making.

September: Frank Davis made a presentation "Sensitivity of fire regime in chaparral ecosystems to global climate change," at the Symposium on Anticipated Effects of a Changing Global Environment on Mediterranean-type Ecosystems, Valencia, Spain (with J.C. Michaelsen).

October: Frank Davis lectured on "Integration of remote sensing and GIS for environmental analysis," at the Department of Geography, University of North Carolina at Chapel Hill, and on "GIS analysis of biodiversity in California" as the Hanes Visiting Scholar.

October 2-3: The 4th Annual Atlantic Institute Seminar was held at the University of Maine. Session 1 on Spatial Data Models and Spatial Data Structures was moderated by Langley Willauer. GIS-related papers presented at this session include: "Image Schemata: The Structure of Spatial Concepts," Rong-Her Chang; and "Topological Relations," Jayant Sharma. Session 2 on Surveying, Geodesy and GPS was moderated by Khaled Al-Taha. Session 3 on Automated Cartography was moderated by Max Egenhofer. GIS-related papers presented at this session include: "Graph Theory in Automated Map Design," William Mackaness; "Modeling Transformations of Settlements from Geographic to Cartographic Space," Douglas Flewelling; and "A Direct Manipulation User Interface for Exploring Geographic Information, Jim Richards. At Session 5 on Image Processing and Spatial Databases, Steve Frank presented "Cataloging Paradigms for Spatial Metadata." Session 6 on GIS Applications was moderated by Barbara Bicking.

October 10: Michael Goodchild participated in a panel discussion, League of California Cities annual meeting, Los Angeles, CA.

October 13: Michael Goodchild presented a "GIS overview" at Hitachi Research Laboratory, Japan.

October 13: Michael Goodchild gave a presentation on "GIS research and the NCGIA" at the first annual meeting, GIS Association of Japan, Tokyo.

October 19: Kate Beard and William Mackaness attended the IEEE Visualization ’92 Workshop on Automated Design of Visualizations, Boston, MA, and gave a workshop on Visualization Requirements for Spatial Data Quality.

October 23-25: Luc Anselin presented the paper "Conjuncture, confession, context and class: spatial analysis of Nazi party (NSDAP) support in the 1930 election in the Weimar republic" (co-authored with John O’Loughlin and Colin Flint) at the conference on "Spatial and contextual models of political behavior," NCGIA Buffalo.

October 27-28: David Tyler attended the IEEE Oceans ’92 Conference, Newport, RI, and organized and moderated a session with Bryan Pearce on "GIS in a Marine Environment."

October 29 - November 13: Mike Batty visited the Laboratory of Resources and Environmental Information Systems (LREIS) in the Chinese Academy of Sciences, Beijing, with whom the Buffalo site has a cooperative agreement, where he presented a series of lectures on urban planning and GIS. He also visited the Institute of Remote Sensing in the Academy and the Remote Sensing Training Center in Peking University. Batty lectured to two groups of urban planners and policy makers whose training in this area is under the auspices of the UNDP and the World Bank.

November: Frank Davis made a presentation on "Plant Communities of the Easterm Mojave Desert," at the Eastern Mojave Desert Symposium, Riverside, California.

November 2-4: Stewart Fotheringham attended the Fall Meeting of the Operations Research Society of America and The Institute of Management Scientists (ORSA/TIMS) in San Francisco, and presented a paper co-authored with Paul Densham entitled "The Zone Definition Problem in Location-Allocation Modeling", at a special session on Spatial/Location Modeling in Marketing/Retailing. From Santa Barbara, Richard Church presented papers on "Forest planning and management using large scale linear programming" (Co-authors A.T. Murray and S.R. Loban) and "The reliability of Alpha reliability" (Co-author A.T. Murray).

November 6-14: Hugh Calkins, Paul Densham, Yuemin Ding, David Mark, Peter Rogerson, and Victor Wu attended GIS/LIS ’92 in San Jose. Mark, Ding, and Rogerson presented papers published in the Proceedings. Other presentations by Buffalo personnel included Calkins on "Elements of a Taxonomy for Spatial Data Sharing", and Wu on An Interactive Visualization Language for Exploratory Spatial Data Quality". Densham instructed a workshop with Michael Goodchild on "Introduction to Spatial Analysis", and organized a session (chaired by Marc Armstrong of Iowa) on
spatial decision support systems. Mark chaired a session on "Advances in Algorithm Development for GIS". From Maine, the conference was attended by Kate Beard, William Mackaness, Sarah Clapham, and Harlan Onsrud. Beard and Mackaness organized a session on "Visualization of Spatial Data Quality." Clapham presented "A Formal Approach to the Visualization of Spatial Data Quality" at this session. Onsrud gave a presentation on "Spatial Data Cost Recovery: Policies Underlying the Approaches." From Santa Barbara, Frank Davis was a session organizer (with David Stoms) on "Integration of Spatial Technologies for Environmental Modeling". Michael Goodchild made presentations on "A user perspective on quality control", "Towards a national research agenda in GIS", "The most appropriate discipline for GIS", and "Findings and recommendations of the Governor’s Geographic Information Task Force". Steve Palladino presented "Charting the course for GIS in the secondary schools" and Waldo Tobler participated in a panel discussion on "UCGIA".

November 13-15: Peter Rogerson attended the North American Regional Science Meetings in Chicago, and presented a paper entitled "GIS and Population Analysis: A Survey", in a special session on GIS and Spatial Analysis, and an invited paper entitled "A Question of Balance", at a special session on the future of regional science. Luc Anselin presented "Linking GIS and spatial data analysis in practice". Richard Church presented (with co-author A.T. Murray) "Vehicle availability and estimating service coverage," and (with co-author O.B. Schoepfle) "A fast network-based hybrid heuristic for ’controlled choice’ assignments".

November 15-16: Bob Franzosa attended the Conference on Vision Geometry, Boston, MA, and presented "Topological Spatial Relations Based on Components and Dimensions of Set Intersection," co-authored by Max Egenhofer.

December: Frank Davis served on a Technical Advisory Panel, EPA EMAP Landscape Characterization program, Las Vegas, Nevada.

APPENDIX 3 - VISITORS TO NCGIA SITES

Obeid Ahmed, Sharjah Municipality of the United Arab Emirates
Mohamad Aldada, Sharjah Municipality of the United Arab Emirates
Abdulla Al-Hamar, GIS Project Coordinator, Center for GIS, State of Qatar
Mohamed Ali, Girl's College at Riyadh, Saudi Arabia.
Ali Alrasheed, Sharjah Municipality of the United Arab Emirates
Nils-Thore Andersson, Malmo Government Offices, Malmo Sweden
John Armstrong, IBM Corp.
Marc Armstrong, Department of Geography, University of Iowa
Douglas Ashby, Attorney
Richard Aspinall, Macaulay Land Use Research Institute, Aberdeen, Scotland
Lencho Auchstetter, City of Santa Barbara Planning Division
Mohammed Aziz, Lecturer in Cartography at the University of Qatarbejamin
Kenji Baba, Hitachi America Ltd.
Errol Bamcord, Dept. of Geography, University of Adelaide, Australia
Kathy Barbieri, Theory Center, Cornell University
Emilio Barisano, GIS consultant, Antibes, France
Robert Barr, University of Manchester, UK
Renato Barrera, Intergraph Corporation
Kata Bartilon, California Fish and Game
Christopher Barton, USGS - Denver
Eckhard Bartsch, Praesident des Hessischen Landesvermessungsamtes & AdV Representative
Paul Beier, Cooperative Extension - UC Berkeley
Ted Belling, Niagara County Planning and Urban Development
Roberto Benedetti, Telespazio (Italy)
Jerry Benjamin, Rockefeller Foundation
Ralf Bill, University of Stuttgart, Germany
Ian Bishop, School of Architecture and Planning, Melbourne University
Michael Blakemore , University of Durham, England
Aaron Bloch, Provost, University at Buffalo
Ralf Borchert, AdV - Coordinator Foreign Exchange Landesvermessungsamt-Hessen
Mike Botts, NASA Goddard
David Boyce, Hitachi America Ltd.
Carola Braun, University of Bonn, Germany
David Brody, Pack, Hartmen, Ball & Huckabone
Charles Brown, City of Santa Barbara Planning Division
Peter Brussard, U. Nevada-Reno
John Bulega, ESL, Sunnyvale CA
Rosty Caryk, Beak Consultants, Inc.
Tom Chatfield, Oak Ridge National Labs, Oak Ridge, TN
Fredric Chiffelle, Professor of Human Geography, University of Neuchatel
Raju Chitambaram, Loral Command and Control Systems, Colorado Springs, CO
Keith Clarke, Hunter College and USGS
Susan Cochrane, California Fish and Game
Dan Cole, Smithsonian
Jeff Cole, Resolution Mapping
Gary Comer, Maptech
Shirley Connor, Town Supervisor, Pendleton
Timothy Cooke, NYS DEC - Regulatory Affairs
Knight Coolidge, Maptech
Frank Costa, Department of Geography and Planning, University of Akron
Danette Coughlin, Naval Research Lab, Mississippi
Michael Courneen, IntelliGIS
Mike Crane, USGS Denver
Ferko Csillag, University of Syracuse
Cui Gonghao, Department of Geo and Ocean Sciences, University of Nanjing
William Culbreth, National Supercomputing Center, Las Vegas, NV
Julio D'Alge, INPE Brazil

Dora N. Salvatierra de Desjardins, National University of Tucuman
Maria Adela Igarzabal de Nistal, University of Buenos Aires, Argentina
Jeff Dietz, NYS DEC
Steven Doleski, NYS DEC - Region 9
Claus Dorenbeck, Andersen Consulting, Hamburg, Germany
Robert Dufresne, CGI Group, Montreal, and the VOLVOX Research Center
D.J. DuPlessis, Division of Roads and Transport Technology (Republic of South Africa)
Geoffrey Dutton, HDM
Samuel Dwyer III, UCLA School of Medicine
Peter Eberhardt, Cartographer, USDA Forest Service, Eugene, OR
Patricia Eble, City of Santa Barbara Planning Division
Paul Eccleson, Hewlett Packard, Bristol UK
JoAnne Ellsworth, Niagara County Department of Environmental Management
Schiro Enbutsu, Hitachi America Ltd.
Hank Emery, Emery & Associates, Inc., Greenwood Village, CO
Kurt Fedra, IIASA (International Institute of Advanced Systems Analysis
Manfred Fischer, University of Vienna
Jim Fisher, Ventura County Public Works Agency
Peter Fisher, Department of Geography, University of Leicester
Wolfgang Forstner, University of Bonn, Germany
Suxin Fu, LREIS, Chinese Academy of Sciences
Ramez Gerges, Caltrans
Suchi Gopal, Boston University
Myles Gould, University of Bristol
Kendrick Greer, USDA Forest Service, Ft. Collins, CO
Herman Gucinski, MANTECH Environmental Technology Inc
Martin Haas, U.S. Department of Energy
Susan Hanson, Clark University
Bill Hazelton, U of Melbourne, Australia
Frederick B. Henderson III, Geosat Committee President, Norman OK
Vince Hesketh, Artificial Intelligence Lab of Eastman Kodak
Juei Hu, LREIS, Chinese Academy of Sciences
Wendi Hu, Santa Barbara
Huang Xuang, National Remote Sensing Center of China, Beijing
R.A. Humphrey, Westinghouse
Jeff Jackson, ESRI
Robert Jacobson, U.S. Geological Survey, Water Resources Division
Stefan Jensen, ESRI Germany
Christopher Jones, Cambridge University
Gabor Kakoury, Budapest, Hungary
Smith Kampempool, World Environment Institute, NYC
Mark Kandel, NYS DEC - Region 9
Robert Kemp, Ocean Drilling Program
Bruce Kershner, Great Lakes United
Stanley Keysa, Economic Development Coordinator for Erie County
John Kick, U.S. Soil Conservation Service
Satomi Kobayashi, Hitachi America Ltd.
Sachio Kubo, Keio University, Kanagawa, Japan
David Landgrebe, Purdue University
Mike Landi, Vice President for Sponsored Programs, University at Buffalo
Art Lange, Trimble Navigation Systems
Joseph Latona, Town Engineer, Clarence
Vanessa Lawrence, Longman Publishers
Jiang Li, Arizona Remote Sensing Center, U of Arizona, Tucson
Robert Likvar, US Army Corps of Engineers
Vladimir Lovitsky, Kharkov College of Computer Science, Ukraine
Tom Lupo, California Fish and Game
Kevin MacDougall, University of Queensland, Australia
David Maidment, University of Texas
Bernhard Manerhof, Arnimatr, Munich, Germany
Karen Manning, Town Assessor, Pendleton

Bob Martin, Western New York Technology Development Center
Ewan Masters, University of New South Wales, Sydney, Australia
Paul Mather, Natural Environmental Research Council, University of Nottingham
Yasuo Matsuda, Hitachi America Ltd.
R. Steven Maxwell, Recra Environmental Inc.
Melinda McClanahan, New Mexico Highlands University, Las Vegas
Ike McKim, Army Corps of Engineers
Carlos Mendoza, Ventura County Public Works Agency.
Gunther Meyer, CSIR, South Africa
David Miller, Macaulay Land Use Research Institute, Aberdeen, Scotland
Martin Misseyer, Free University of Amsterdam
Milton Moeschlin, City of Santa Barbara Planning Division
Warren Moran, University of Auckland
Cathy Muller, ESRI
Denis Murphy, Stanford
Reed Noss, U. Nevada-Reno
Milton Nunez, Bureau of Museums, Government of the Oland Islands, Finland
John O'Leary, SDSU
J.J. Olivier, Department of Water Affairs, Republic of South Africa
Bernard Ostendorf, UC Davis
Donald Owens, Earth Dimensions, Inc.
Don Paige, Geological Survey of South Africa at Pretoria
Daniela Palma, ENEA (Italy)
Heping Pan, University of Bonn, Germany
Brad Parks, EPA Great Lakes
Michael Patterson, W. Schutt and Associates
Mario Paula, U.S. E.P.A. - Region II
Timothy Perkins, SAC College, Edinburgh, Scotland
Fritz Petersohn, BSC Group, Boston, MA
Tom Poiker, Department of Geography, Simon Fraser University
Michael Powers, Santa Barbara County Assoc. of Governments
David Pullar, ESRI
James Quinn, UC Davis
Michael Raab, Erie County Department of Environmental Planning
Gerald Rasmussen, NYS DEC - Habitat Inventory
Bruno Rati, ESRI Italia (Telespazio)
William Reiners, University of Wyoming-Laramie
Patricia Riexinger, NYS DEC - Wetlands Program
Kelly Robinson, Pacific Grove, CA
Ken Roblee, NYS-DEC Region 9
Augustin Rodriguez-Bachiller, School of Planning, Oxford Polytechnic
Tom Rowland, U.S. Department of Energy
Stephan Ruwiedel, University of Bonn, Germany
Malcolm Sabin, Dept. of Industrial Studies, U of Liverpool, UK
Rafael Moreno Sanchez, National Institute of Investigations, Chapingo, Mexico
Wolfgang Schickler, University of Bonn, Germany
Paul Schwarz, Theory Center, Cornell University
Julia Seixas, Universidade Nova de Lisboa (Portugal)
Monika Sester, University of Bonn, Germany
Philip Settem, Ventura County Public Works Agency
Gurmukh Singh, University of Durham, England
Amy Skrzypek, Niagara County EMC
Mary Sonntag, Erie County Department of Environmental Planning
Michael Soule, UC Santa Cruz
Louise Southby, U of Melbourne, Australia
Jim Stackelford, USDA Forest Service, Santa Barbara
Judy Stevens, NYS DEC
Lou Steyaert, USGS Reston
Michael Stonebraker, UCB Computer Science
S. Subbiah, Department of Geography, University of Madras
Daniel W. Sullivan, Jr., U.S. Department of Energy

Junjie Sun, Environment Bureau of the Chinese Academy of Sciences
Denis Tesson, CGI Group, Montreal, and the VOLVOX Research Center
Jean Claude Thill, University of Georgia
John Tiefenbacher, Rutgers University, NJ
John Townshend, Geography, U. Maryland, College Park
William Tyne, Pratt & Huth Associates
Gary Volta, Resolution Mapping
Paul Walker, CSIRO Wildlife and Ecology, Canberra, Australia
Nancy Walsh, Research Foundation of SUNY, central office in Albany
Stephen J. Walsh, U. North Carolina at Chapel Hill
Jan Wang, Syracuse University
Wang Yinan, State Statistical Bureau (PRC)
Oscar Weser, President, Aerial Fotobank Inc., San Diego
John Whitney, U.S. Soil Conservation Service
Mike Wilson, Department of Geography at Fredonia State College, NY
R.J. Williams, Defence Science and Technology Organisation (Australia)
Mike Worboys, University of Keele, UK
Bingfang Wu, LREIS, Chinese Academy of Sciences, Beijing
Xia Guixiang, State Statistical Bureau (PRC)
Zhao Xueying, Ministry of Water Resource, Zhengzhou, China
Zhong Zhangzi, State Statistical Bureau (PRC)
Albert Zobrist, Rand Corporation
Gary Zon, Artificial Intelligence Lab of Eastman Kodak

APPENDIX 4 - COURSES TAUGHT BY NCGIA FACULTY

1. Santa Barbara

Computational Concepts, Fall 1992, Richard Johnson

Geographic Photo Interpretation, Fall 1992, Jeff Star

Special Topics in Cartography, Fall 1992, Waldo Tobler

Uncertainty in Spatial Decisions, Fall 1992, Helen Couclelis

Introduction to Geographic Data Analysis, Fall 1992, Luc Anselin

Introduction to Geographic Information Systems, Fall 1992, Michael Goodchild

Urban and Environmental Systems Analysis, Fall 1992, Richard Church

Analytical Methods for Geographers, Fall 1992, David Siegel

Environmental Perception and Cognition, Fall 1992, Daniel Montello

Introduction to Spatial Decision Making, Winter 1992, Reginald Golledge

Remote Sensing Techniques, Winter 1992, Leal Mertes

Groundwater Hydrology, Winter 1992, Hugo Loaiciga

Production Cartography, Winter 1992, David Lanter

Technical Issues in GIS, Winter 1992, Michael Goodchild

Seminar in Cartography, Winter 1992, Waldo Tobler

Advanced Location and Transport Systems, Winter 1992, Richard Church

Intermediate Remote Sensing, Spring 1992, Leal Mertes

Earth System Science, Spring 1992, Catherine Gautier

Application Issues in GIS, Spring 1992, Michael Goodchild

Digital Remote Sensing, Spring 1992, Leal Mertes

Methods in Regional Analysis, Spring 1992, Luc Anselin

Introduction to Cartographic Programming, Spring 1992, David Lanter

2. Maine

Introduction to Geographic Information Systems, Fall 1992, Kate Beard

Engineering Databases and Information Systems, Fall 1992, Max Egenhofer

Casco Bay GIS, Fall 1992, Kate Beard

Municipal GIS, Fall 1992, Kate Beard

Environmental Law and Resource Regulation, Fall 1992, Harlan Onsrud

Computer Law, Fall 1992, Harlan Onsrud

Graduate Seminar, Fall 1992, David Tyler

Map Generalization, Fall 1992, Kate Beard

Object Oriented GIS, Fall 1992, Max Egenhofer

Multi-Media GIS, Fall 1992, Kate Beard

Visualization of Spatial Data Quality, Fall 1992, Kate Beard

Cadastral Systems, Spring 1992, Harlan Onsrud

Land Development Design, Spring 1992, Harlan Onsrud

Geometry & Computer Graphics, Spring 1992, Wolfgang Kainz

GIS Applications, Spring 1992, Kate Beard

GIS User Interfaces, Spring 1992, Max Egenhofer

Casco Bay GIS, Spring 1992, Kate Beard

Graduate Seminar, Spring 1992, David Tyler

Research Methodologies for GIS, Spring 1992, Max Egenhofer

Automated Generalization, Spring 1992, Kate Beard

3. Buffalo

Maps and Mapping, Spring 1992, Mark

Cartographic Design, Spring 1992, Buttenfield

Multivariate Statistics in Geography, Spring 1992, Fotheringham

Population Geography, Spring 1992, Rogerson

Locational Analysis, Spring 1992, Densham

Cartographic Practicum, Spring 1992, Mark

GIS Applications, Spring 1992, Calkins

Introduction to GIS, Spring 1992, Mark

Research Design, Spring 1992, Rogerson

Introduction to Graduate Cartography, Spring 1992, Buttenfield

GIS Algorithms and Data Structure, Spring 1992, Mark

Census Data and Their Use, Spring 1992, Calkins

Advanced Topics in GIS, Spring 1992, Mark

Advanced Topics in GIS, Spring 1992, Densham

Graduate Internship, Spring 1992, Rogerson

Advanced Research Seminar, Spring 1992, Rogerson

Geographic Perspectives and World Issues, Fall 1992, Calkins

Maps and Air Photos, Fall 1992, Buttenfield

Biogeography, Fall 1992, Jelinski

Cartographic Internship, Fall 1992, Buttenfield

Univariate Statistics in Geography, Fall 1992, Jelinski

Cartographic Practicum, Fall 1992, Buttenfield

Introduction to GIS, Fall 1992, Densham

Introduction to GIS, Fall 1992, Mark

Computer Cartography, Fall 1992, Buttenfield

Spatial Decision Support Systems, Fall 1992, Densham

GIS Design, Fall 1992, Calkins

Advanced Topics in Cartography, Fall 1992, Buttenfield

Advanced Topics in GIS, Fall 1992, Mark

Advanced Land Use Analysis, Fall 1992, Batty

Advanced Research Seminar, Fall 1992, Fotheringham

APPENDIX 5 - GRADUATE DEGREES GRANTED AT NCGIA SITES

1. Santa Barbara

Schweizer, Diane, MA, Fall 1992, Data quality and choropleth maps: an experiment with the use of color (Goodchild, Lanter, Michaelsen).

Bueno, Michael, MA, Fall 1992, Quantification of cartographic generalization in land cover maps using spatial pattern index measurements derived from digital satellite imagery (Davis, Estes, Goodchild).

Lombard, Kristi, MA, Fall 1992, Generating alternatives in corridor location (Church, Couclelis, Goodchild).

Ruggles, Amy, MA, Fall 1992, An analysis of late-horizon settlement patterns in the Temascalapa-Teotihuacan basins: the creation of idealized settlement patterns through location-allocation models and GIS (Church, Anselin, Goodchild).

Hudak, Sheri, MA, Fall 1992, Spatial econometrics in practice (Anselin, Goodchild, Michaelsen).

Marotti, Andrea, MA, Fall 1992, A bio-optical model of primary production for application in the Antarctic marginal ice-edge zone (R. Smith, Prezelin, Siegel).

Shu, Shourong, MA, Winter 1992, Dynamic 3D display of the globe using a hierarchical triangular data model (Goodchild, Tobler, Estes).

Walter, Richard, MA, Winter 1992, Community models of species richness: regional variation of plant community species composition on the West Slope of the Sierra Nevada (Estes, Davis, Haller).

Loban, Scott, MA, Spring 1992, A heuristic for an interactive decision support approach for timber harvest scheduling (Church, Jones, Anselin).

Shi, Jiancheng, PhD, Winter 1992, Radar polarimetric modeling and observations of snow-covered terrain (Dozier, R. Smith, Davis, Zebker, R. Davis).

Haston, Laura, PhD, Spring 1992, Reconstruction of spatial and temporal patterns of precipitation variability in Southern California using tree-ring chronologies (Michaelsen, Dozier, Loaiciga, Keller).

Kumler, Mark, PhD, Summer 1992, An intensive comparison of TINs and DEMs (Goodchild, Tobler, Church, Mark).

Painho, Marco, PhD, Summer 1992, Modeling errors in digital land use/land cover maps (Davis, Goodchild, Estes, Haller).

Ehrlich, Daniele, PhD, Summer 1992, Multi-temporal satellite image analysis for crop inventories in the Po river valley (Estes, Davis, Jones, Hall).

Wang, Yong, PhD, Fall 1992, Radar backscatter modeling and applications in forested environments (Davis, Melack, Dozier, Freeman, Paris).

McGwire, Kenneth, PhD, Fall 1992, Comparison of standard multispectral and map assisted classification methods with a new layered approach (Estes, Davis, Goodchild, Star, Botkin).

Kemp, Karen, PhD, Fall 1992, Environmental modeling with GIS: a strategy for dealing with spatial continuity (Goodchild, T. Smith, Tobler, Haymon).

Kennedy, Susan, PhD, Fall 1992, An investigation into the geography of breast cancer: the small number problem in small areas (Tobler, Anselin, Couclelis, Williams).

2. Maine

Khaled Al-Taha, PhD (Surveying Engineering), August 1992, "Temporal Reasoning in Cadastral Systems" (Frank, Barrera, Beard, Egenhofer, Onsrud).

Taher Buyong, PhD (Surveying Engineering), January 1992, "Measurement-Based Multipurpose Cadastral Systems" (Frank, Hintz, Kuhn, Egenhofer, Tyler).

Sarah Clapham, MSc (Surveying Engineering), August 1992, "A Formal Approach to the Visualization of Spatial Data Quality" (Beard, Frank, Onsrud).

Sabine Timpf, MSc (Surveying Engineering), August 1992, "A Comparative Study of Navigation in the U.S. Interstate Network and the German Autobahn System" (Egenhofer, Frank, Herring).

Gary Volta, MSc (Surveying Engineering), August 1992, "Interaction with Attribute Data in Geographic Information Systems: A Model for Categorical Coverages" (Egenhofer, Frank, Beard).

3. Buffalo

Sami Alamiri, MA (Calkins). GIS for the Assessment of the Potential Population Supporting Capacities of Land in Developing Countries (February 1992)

Theresa Ford, MA (Fotheringham). Cross Border Shopping Between Canada and the United States: An Overview and Consumer Survey Results (February 1992)

Jim McKinney, MA (Buttenfield). Evaluation of Visual Tools for Location Modeling (February 1992)

Nicole Soltyka, MA (Buttenfield). Comparing Raster and Vector GIS with Digital Terrain (February 1992)

David Carey, MA (Buttenfield). Use of Federal Digital Data Products with ARC/INFO (May 1992)

John Sheperd, MA (Jelinski). A quantitative analysis of Georgia phytogeography (September 1992)

Geoffrey Wright, MA (Buttenfield). GIS Adoption in Third World Village Planning (September 1992)

Hsueh-Cheng Chou, PhD (Mark). Designing a Programming Language for Geographic Modeling (September 1992)