UC Santa Barbara

NCGIA Closing Reports on Research Initiatives and Projects

Title
NCGIA Annual Report, Year 1

Permalink
https://escholarship.org/uc/item/7z95h3wj

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Publication Date
1990-02-01

NATIONAL CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS

ANNUAL REPORT

Year 1
(December 1, 1988-November 30, 1989)

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

February 26, 1990

**NATIONAL CENTER FOR GEOGRAPHIC INFORMATION
AND
ANALYSIS**

ANNUAL REPORT

December 1, 1988-November 30, 1989
(Year 1)

SUMMARY

The National Center for Geographic Information and Analysis was announced by NSF on August 19, 1988, and awarded to a consortium of the University of California, Santa Barbara (as lead institution), the State University of New York at Buffalo, and the University of Maine. Funding began December 1, 1988. The Center's mission reflects the desires of the NSF, as expressed in the solicitation document: to advance the theory, methods, and techniques of geographic analysis based on geographic information systems (GIS) in the many disciplines involved in GIS 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; and to provide a central clearing house and conduit for disseminating information regarding research, teaching, and applications.

The Center which has developed in the past twelve months is fully consistent with the proposal submitted to NSF. The Center has been successful in raising substantial additional support for its activities, particularly in the area of equipment. It has involved the external community in many of its activities, not only in outreach, but also in extensive participation in research and education. Numerous activities have drawn attention to the existence of the Center, both in the US and abroad. Finally, considerable effort has gone into refining the external community's view of the Center's purpose and goals, and what can and cannot be expected of the Center's role in the wider field of GIS.

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I   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 a year for five years. The first year's operation officially began December 1, 1988, with funding effective as of that date. The decision to establish the Center and the selection process have been described by Abler (*International Journal of Geographic Information Systems*, 1987, vol. 1, pp. 303-326).

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 data base 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."

The solicitation, which appeared in mid-1987, attracted intense interest. GIS, though emerging as a significant industry, was not identified clearly with any academic discipline and had few of the usual symbols of academic engagement-journals, societies, textbooks, etc. NSF's willingness to commit major funding for basic GIS research has given the field a new level of visibility, not only as a tool for management and mapping, but as a powerful technology for scientific analysis and research.

The decision to channel funding through NSF's Geography and Regional Science Program and Division of Social and Economic Science, unlike previous centers established in science and engineering, has reinforced belief that GIS is an enabling technology for a wide range of sciences dealing with spatially distributed phenomena.

At the time of the establishment of the NCGIA by the National Science Foundation in 1988, there was mounting concern over the appropriate balance between the funding of natural and social sciences and a rapidly growing public concern over environmental issues. Since these trends in the external world are bound to influence future research and educational directions of the Center, the same issues are raised here in a GIS context in order to foreshadow future initiatives by the Center.

The first trend with significant implications for GIS and the Center is this growing concern about global-scale issues, particularly global environmental change and its human dimensions. Geographic Information Systems have a significant potential role to play in supporting the sciences that will tackle these problems, but at the same time a series of impediments may preclude the fulfillment of that role. These impediments include volumes of data far beyond the limits of current GIS; visualization problems in dealing with data distributed over a curved surface; modeling problems in analyzing error propagation through large, non-linear systems; lack of suitable hierarchical structures to handle multi-scale data; and

incompatibilities between current image processing systems and GIS, since remote sensing will be a major source of global environmental data.

A second issue facing the Center is the balance between GIS applications in the natural, health, and social sciences. Digital spatial data has a more established role in natural science, supporting studies of the environment and its resources, than in the social or health sciences. Yet there is ample reason to suppose that GIS technology has as much potential in supporting research in such areas as locational factors in marketing, retailing, and provision of public services; spatial variation in health, social well-being, crime, justice, employment, etc.; migration and changing demography; epidemiology and spatial variations in the incidence of disease; and planning, transportation, and the impact of the environment on the quality of life.

Many existing examples of spatial decision support systems are in the areas of resource management. But some of society's most pressing problems are in an area bordering natural and social science. For example, a spatial data base might be built by coding city blocks according to building type, using Topologically Integrated Geographic Encoding and Referencing (TIGER) files as the base, and estimating each block's susceptibility to earthquakes. An SDSS might then model the locations of structural damage and human injury, utilization of evacuation routes, locations of evacuation centers, order of evacuation of each neighborhood, etc.

To date, one of the most common applications of GIS technology in social science has been to archaeology, where it is helping to inventory and understand such problems as the detailed spatial juxtaposition of artifacts at excavated sites and early patterns of human settlement.

To explore the issues involved in encouraging greater use of GIS technology in the social sciences, the Center is planning a conference in 1990 entitled "GIS and Social Science Research: Potentials, Problems and Present Status."

A third issue confronting the center is the nature of the GIS field itself. At present, GIS is a loose collection of interests without strong identification with any one discipline. On the academic side, it has elements of surveying, cartography, geography, environmental studies, forestry, and anthropology. It includes applications in resource management, facilities management, land information, urban government, and mapping. As the field matures, we can expect to see increasing specialization as the community comes to recognize natural divisions within what we now identify as GIS.

Already there are signs that one particular dimension effectively differentiates the community, although it is far from being a clear division at this point. At one end of the continuum are systems designed to support complex decision making, of the sort that occurs in forestry management, where a GIS must provide the information needed to determine cutting schedules, road maintenance, replanting, etc. This type of application has led to the definition of GIS as a spatial decision support technology, and as an enabling technology for scientific research. Such systems are characterized by a data base that may contain many different types and scales of data, and software with a high level of functionality.

At the other end of the continuum are systems that began with the addition of simple geographical access to large existing administrative data bases. For example, a city government may wish to "add geography" to an existing data base of land parcel records. Systems for this

class of application are characterized by fast access, the ability to interface with a variety of data base management systems, and a relatively low level of functionality.

Which way is the field going? Is the second type of application larger in terms of potential market, and will the GIS vendor community be drawn in this direction? Or will two types of vendor emerge? Or are the needs of both ends similar enough to prevent a split in the field? From the Center's perspective, do both ends share common problems and impediments that can be addressed with a single research agenda and single education strategy, or should the Center focus on one direction at the expense of the other? At this time the former strategy is clearly the more appropriate of the two, but the picture may be entirely different in a few years.

This issue is of key importance for GIS as a technology for scientific research. There are several possible analogies for the potential role of GIS as a software package supporting a wide range of scientific disciplines. Word processing, for example, developed to a large extent in response to the office automation market, but found a compatible market in academic writing and publishing. Packages to support statistical analysis, such as SAS and SPSS, were developed largely to satisfy a scientific market. But, like word processing, GIS has been driven by the applied marketplace, and scientific applications have only recently begun to emerge. The danger is that the applied market will continue to develop more strongly and will begin to move in a different direction from the scientific market.

A community with the energy and growth exhibited by GIS in the last few years needs a strong presence at the national level if it is to assist effectively in formulating national policy and coordinating orderly development of the field. Ideally, it must have simple organizational and institutional structures and a federal agency with clear responsibility in the area. But GIS is comparatively new and includes a wide variety of interests and approaches, so any radical reorganization seems unlikely in the near future.

Clearly, NCGIA's role lies in doing basic research, promulgating the results to the community as a whole, and working to improve the quality and availability of GIS education. To do so it needs strong ties with similar organizations in the United States (such as ACSM and the Urban and Regional Information Systems Association) and in other countries.

If one considers the current and potential scale of the industry (several estimates project a $200 to $300 million range) and the level of interest in GIS indicated by attendance at conferences, NCGIA's annual budget represents a low level of investment in research and development. Consequently, the Center has developed strong ties with other GIS research universities and national laboratories in an effort to coordinate activities and increase the total resources of funding and expertise that we can collectively bring to bear on the research agenda.

2.   SUMMARY OF MAJOR ACTIVITIES.

a.   Research.

The consortium proposed a research plan built around the concept of "impediments": that GIS technology had a significant potential, but that numerous roadblocks needed to be overcome. Some obstacles were technical, such as the unfriendliness of many user interfaces; some were institutional, such as the lack of standards for digital geographical data; and others

were social and economic, including the difficulty of assessing costs and benefits of GIS, and lack of understanding of the impacts of GIS technology on organizations.

Research at the Center is organized around the systematic removal of these impediments, within the five areas suggested in the solicitation document. The full text of the research plan has been published in *the International Journal of Geographic Information Systems* (1989, vol. 3, pp. 117-136).

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 are identified and ranked and a feasible research agenda for the initiative is defined. Research continues intensively for 18-24 months, with teams of faculty (NCGIA or other), postdoctoral fellows, or advanced graduate students, as well as representatives from private industry or governmental agencies, working in teams on specific problems. The Initiative ends with a national forum to present all of 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. During the first year, five research initiatives were begun, with Specialist Meetings each attended by 25-55 participants from universities, industry, and government:

1. *Accuracy of Spatial Data Bases*. Leader: Michael F. Goodchild (Santa Barbara). Specialist Meeting: Santa Barbara, December 1988.
2. *Language of Spatial Relations*. Co-Leaders: David M. Mark (Buffalo), Andrew U. Frank (Maine). Specialist Meeting: Santa Barbara, January 1989.
3. *Multiple Representations*. Leader: Barbara P. Buttenfield (Buffalo). Specialist Meeting: Buffalo, February 1989.
4. Use and Value of Geographic Information. Co-Leaders: Harlan Onsrud (Maine), Hugh Calkins (Buffalo). Specialist Meeting: Maine, May 1989.
5. *Design and Implementation of Large Spatial Data Bases*. Co-Leaders: Terence R. Smith (Santa Barbara), Andrew U. Frank (Maine). Specialist Meeting: Santa Barbara, July 1989.

Initiative 1: Accuracy of Spatial Data Bases. Many GIS users are aware of the problems that result from inaccuracies or errors in spatial data, and the way these propagate through GIS operations. The major goals of the initiative are to improve models of uncertainty, to develop methods of encoding and tracking uncertainty in data bases, to formulate methods of computing and communicating error in GIS products, and to identify policies that encourage the implementation of accuracy assessment.

At the Specialist Meeting in Santa Barbara, three major premises were examined:

- All spatial data are of limited accuracy;
- Precision in GIS processing normally exceeds the accuracy of the data;
- There is no adequate means for characterizing the accuracy of spatial data, for tracking uncertainty through GIS processes, or for computing and reporting uncertainty.

Besides NCGIA personnel, forty-one attendees represented interested federal agencies including the Geological Survey, the Census Bureau, and NASA, as well as U.S. and foreign universities (Zurich and Rome) and private sector organizations such as TYDAC, Intergraph,

Prime, The Institute for Market and Social Analysis, and Environmental Systems Research Institute. The format of the meeting was a continuous series of half-hour presentations by each of the participants, followed by discussion. Notes were taken and transcribed on the premises for almost immediate distribution to the attendees for their corrections and revisions. The Specialist Meeting Report was published by NCGIA as Technical Paper 89-1.

Initial discussion centered around the issue of living with inaccuracy. There is no way to banish errors from the data base, so what approach is best for dealing 'with uncertainty? Where does the responsibility lie-with the data base itself or with the end user of the data? Can inaccurate data produce accurate output? The more data layers, the greater the chance of contamination, but by the same token, the more data layers, the more information on which to base a decision. Indeed, a trained analyst can look at two inaccurate images and improve on the accuracy of both. It was agreed that inaccurate data, if correctly analyzed, can produce valuable information.

A number of clear-cut items were identified as key issues. First, it was decided that a taxonomy, or classification scheme, of error must be developed and some general observations made on how those errors are handled at the present time. Secondly, there should be a systematic approach to defining how error propagation occurs across the range of GIS operations. In respect to error modeling in Initiative 1, most of the work will be centered on incremental advances due to the complex and difficult nature of the problem. It was suggested that a bibliography and workshop be developed as part of the Center outreach program; the bibliography was prepared and annotated by Howard Veregin and issued as NCGIA Technical Paper 89-9. In addition, a book is being published from the proceedings (*Accuracy of Spatial Data Bases*, published by Taylor and Francis in December 1989). Finally, to raise user awareness of the problem, a bibliography/ taxonomy of spatial data errors has been prepared by Howard Veregin and issued as NCGIA Technical Paper 89-12.

Research has now been underway for about a year. Santa Barbara researchers are simulating stochastic process models of error for large arrays of pixels using a grant of time on the supercomputer at the IBM Palo Alto Research Center; the simulations will be used to estimate the uncertainty of various GIS products, given known levels of uncertainty in the underlying data base. Maine researchers are simulating uncertainty in connection with studies of the sliver problem in polygon overlay. Other Santa Barbara researchers (including visitors from the University of Sheffield and the University of Rome) have been studying the uncertainties in social and economic data resulting from aggregations by reporting zones; error propagation through GIS processes (with USGS support); and finite resolution data structures, particularly for global data sets (Technical Paper 89-5).

Initiative 2: The Languages of Spatial Relations. There are considerable differences in the ways spatial data are structured and processed in GIS, and in the ways people learn and reason about spatial information. These gaps will have to be understood and dealt with if user interfaces are to be improved substantially. The Specialist Meeting was held in Santa Barbara in January 1988. A group of 26 participants from the fields of linguistics, geography, computer science, and engineering held directed discussions rather than formal presentations. The specialists focused their discussions on such topics as Standard Query Languages (SQL), user interfaces, algebraic topology, natural language understanding, knowledge representation, cognitive science, navigation, and way-finding. One day was spent identifying specific areas of

investigation that would be practical for the Center research cycle. The full report of the meeting and the Initiative Research Agenda are available as NCGIA Technical Papers 89-2 and 89-2A.

Seventy-one persons are currently on the 1-2 mailing list. As of September 1989, twenty-one I-2 papers had been accepted or published in proceedings volumes, as book chapters, or in refereed journals; three NCGIA reports had been published (88-6, 89-2, 89-2A), and two 1-2-related Ph.D. theses had been accepted (University of Maine; Swiss Federal Institute of Technology [ETH Zurich]). Sessions are being organized for the AAG Annual Meeting (Toronto, April 1990), and the Fourth International Symposium on Spatial Data Handling (Zurich, July 1990).

Current work involves wayfinding, driving directions, and spatial knowledge acquisition; cross -linguistic spatial terms and landscape generics; cross-linguistic analysis of locative expressions and studies of linguistic variation in natural language terms for spatial relations; vehicle navigation aid systems; user interfaces, including research on multi-media interfaces; computer generation programs and other cognitive aspects of GIS interfaces; metaphors for conveying and perceiving spatial information; the visualization of spatial relations; formal definitions of topological relationships, metrical relationships, algebras of spaces and morphisms between spaces; and non-quantitative query languages and reasoning about space.

Initiative 3: Multiple Representations. Although the ability to change the scale of a display is one of the more immediately attractive features of a GIS, scale and spatial resolution are established clearly by such parameters as raster cell size or the scale of the input document. Complex rules of generalization are needed to convert the representation of a simple feature like a coastline to a smaller scale, and it is extremely difficult to convert it to a larger scale in an appropriate way. As a result, many data bases must include multiple representation of the same geographical feature.

Buffalo was the site of the third Specialist Meeting (February 1989), dealing with this issue of multiple representations of objects in spatial data bases. Thirty specialists were invited to investigate such issues as scale changes, the concept of space, and line generalization. The goal of the meeting was to develop a series of projects that will help define and overcome the impediments to a more effective utilization of GIS graphic capabilities.

Research topics include hierarchical data structures for solving problems of scale-dependent multiple representations of features within a spatial data base; definition of the rules for automating the generalization process; systems for describing the ways features change with scale; and data structures which formalize the logical relationships of multiple representations.

One major product of Initiative 3 is a multi-agency, multi-scale data base intended to serve as a standardized data domain for benchmarking algorithms and establishing comparable results for generalization research. The U.S. Bureau of the Census (TIGER), National Ocean Survey (Shoreline), USGS (DLG) and DMA (DTM) have cooperated in this project. A graduate intern (J. DeLotto, Buffalo) was funded by Census and NCGIA to implement the data base and write unpacking software and documentation. Five sets of data are planned, each containing data from several agencies. NCGIA will disseminate the data sets in the public domain on a cost recovery basis, in both DOS and Macintosh formats (5-1/4" and 3-1/2" for 800K, 1.2MB, and 1.44MB diskettes). Sessions at a national conference (perhaps AUTO-CARTO or LIS/GIS) in 18-24 months will report on actual use by agencies and academic researchers.

An NCGIA (I-3)-Syracuse University symposium, "Towards a Rule Base for Map Generalization," will be held in April, 1990, at Syracuse University, to address substantive and conceptual issues prerequisite to the development of a knowledge base for cartographic generalization. Participants have been invited from universities in America, Canada, Switzerland, The Netherlands and Australia, and from the private sector (Intergraph, Prime-Wild, and Analytical Sciences Corp.); each will present a specific problem.

Initiative 4: The Use and Value of Geographic Information. This Initiative is the first to address social, economic, and institutional issues raised by the adoption of GIS technology. The Specialist Meeting was held in Maine in early May 1989. About 25 experts from many different disciplines met to define how geographic information is used in the decision-making process, how the introduction of an automated geographic information system impacts the quality and quantity of spatial information, and how to put a monetary value on any changes that occur in the decision making processes as a result of the adoption of a GIS.

Three research themes on social, economic and institutional issues emerged at the Specialist Meeting: the need for a taxonomy of geographic information and its uses (what types of geographic information exist and how they relate to the variety of data models of spatial data bases; are certain types of geographic information more or less suitable for handling in spatial data bases; the role of geographic information in human activity, who uses it, and for what purposes); development of objective methods for measuring the value of geographic information; and empirical studies of the diffusion of GIS technology.

A bibliography of I-4 issues is nearing completion, and will be issued as an NCGIA Technical Report. Two I-4-related Ph.D. theses (Maine, Buffalo) are being written. Several NCGIA personnel have held meetings with representatives of the Maine Division of Public Health to discuss potential applications of GIS in the area of epidemiology.

Some I-4 researchers are focusing on the development of techniques for modeling the use of geographic information in decision making, and case studies to test such geographic information use models have been funded (Department of Natural Resources, Washington State; Town of Amherst).

Several proposals are pending to investigate factors influencing the adoption of GIS by designers and facilities managers; factors influencing the extent to which GIS adopters actually utilize its potential; GIS in conflict management; and bureaucratic factors in the adoption of GIS by public organizations.

Responsibility for work on the value of geographic information is centered in Buffalo; responsibility for the other elements is centered in Maine.

Initiative 5: Architecture of Very Large Spatial Data Bases. In July 1989 two meetings were held on this research topic in Santa Barbara: a formal symposium that attracted more than 170 participants from the academic, commercial, and government sectors, and a smaller, more intensive workshop attended by 35 persons, whose goal was to develop the initiative's research agenda.

Initiative 5 will examine the technical problems which arise in handling such large spatial data bases as those now being constructed by the U.S. Geological Survey or anticipated from satellite data from NASA's Earth Observing System in the mid-1990s and beyond.

Initiative 5 is of central significance to the research mandate of the NCGIA, as well as being closely related to I-1, I-2, I-3, and I-12. Spatial data bases are growing in size at a rate that may, at least temporarily, outstrip our abilities to handle them successfully. VLSDB data sets are often heterogeneous and multi-layered, and comprised of a large variety of data types. Nevertheless, such data bases are necessary for studying a wide array of key scientific problems, such as environmental change on a global scale, and for a key number of applications, such as a comprehensive GIS for a large urban area or for major resource management.

At the July "Symposium on the Design and Implementation of Large Spatial Data Bases," sponsored by the NCGIA in conjunction with NASA, the Environmental Protection Agency, Oak Ridge National Laboratory and the Geological Survey, eighteen papers were presented on various topics. Two panels (vendors, academic researchers, and users from the public and private sectors) discussed data base requirements for a GIS and possible data base solutions. The proceedings of this symposium are being published by Springer-Verlag in the "Lecture Notes in Computer Science" series (ed. Buchmann, Gunther, Smith and Wang). The symposium was followed by a three-day workshop, designed to produce a long-term research agenda for Initiative 5.

The workshop alternated between full group sessions and working group sessions. The working groups documented the following key research areas: architecture of GIS data bases; concurrency control; user interfaces; hardware; object modeling; acquisition, capture, integration and maintenance; and extensibility.

b   Education.

The "Core Curriculum Project" is currently the major educational initiative of the NCGIA. Since GIS is a new area of study for most universities and colleges, there exists a demand for comprehensive teaching materials covering the basic theory and concepts, as well as the technical and application issues.

During the 1988-89 academic year, the Center at Santa Barbara, with the help of academic and private sector experts from around the world, developed a comprehensive set of course materials for a year-long introductory sequence in GIS. Designed for instruction at the upper division undergraduate level, these materials consist of 75 sets of lecture notes with overhead and hand-out masters, slides, lists of suggested readings and videos, and twelve laboratory exercises complete with data sets on disk.

The materials in a draft form are now being tested by over 70 educational institutions in the U.S., Canada, Britain, Australia, New Zealand, Hong Kong, and Taiwan. Academic departments represented by test sites include Geography, Environmental Studies, Engineering, Geology, Urban Studies, Surveying, Anthropology, Regional Planning, Forestry, Marine Affairs, and Landscape Architecture.

The evaluation phase has two main objectives. First, is the material comprehensive and does it provide students with useful knowledge and marketable skills? Second, how useful are

the materials to instructors actually preparing and teaching these introductory GIS courses? The results of the evaluation will be of interest not only to the NCGIA, but also to the funding agencies, the users of the curriculum, and the education community in general.

Although the evaluation phase relies primarily on written surveys filled out by both students and instructors using the materials, an emphasis is being placed on direct contact with individual evaluators. Users Group meetings are taking place at GIS/LIS '89 in November at Orlando and at the Annual Conference of the Association of American Geographers in April 1990, at Toronto. By bringing these evaluators together in one place, we hope that some consensus will be reached on issues related to the teaching of introductory GIS in general and the role of the NCGIA Core Curriculum in particular.

The final result of the evaluation phase will be a thorough revision of the draft materials. Although the details of the production of this final version are not yet complete, the materials will be available for wide distribution by the end of July 1990, probably at a cost of approximately $200. Publication information will be widely disseminated prior to release.

C   Outreach.

The establishment of the Center brought an immediate and gratifying response from the GIS community and related interests. In its first year, the Center has had to find a balance between many competing demands in the area of outreach, namely:

1.   Promulgation of research findings, and development of the Center's national and international role as a research institution;
2.   Interaction with the burgeoning GIS industry in the U.S., to ensure that research results are available for utilization and that the Center's research agenda is responsive to industry's needs;
3.   Education and training to help correct the current scarcity of courses and programs and the lack of trained personnel to fill increasing numbers of positions, due to the comparative newness of the field; and
4.   General assistance to the GIS community (academics, consultants, governments and other users of GIS technology), specifically, the provision of advice deriving from the Center's expertise and national role.

Numerous visitors from the US and other countries have toured one or more of the Center's sites, and many presentations about the Center and its research and educational programs have been made by Center personnel, both on and off site. (See Appendices 2 and 3.) Contact has been established with similar organizations in other countries, such as the Regional Research Laboratories funded by the Economic and Social Research Council in the U.K., and some formal agreements for research collaboration have been initiated.

In addition to the Initiative Specialist Meetings, NCGIA hosted or co-sponsored several conferences or workshops. These included:

1)   The International Atlantic Institute Research Seminar on "Land Information Management, Land Tenure, and Cadastral Systems" (Maine; July 27-29, 1989; co-sponsored with the University of New Brunswick and Universite Laval);

2)   The Fifth Annual New York State Geographic Information Systems Meeting (Buffalo, October 16-17, 1989; co-sponsored with the New York State Chapter of URISA);

3)   Northeast Area Remote Sensing System (NEARSS) Association Meeting (Maine, August 25, 1989; co-sponsored);

4)   Advanced Workshop on Movement, Migration, and Transportation: Regional Science Perspectives (Santa Barbara, November 1989; co-sponsored with the International Geographical Union, Commission on Mathematical Models);

4)   Second Annual Geographic Data Workshop (TIGER) (Santa Barbara, August 25, 1989).

A twice-yearly newsletter (June and December) is published, with a current circulation of over 1000; overview presentations on the work of the Center have been made at conferences (see Appendix 2); and stories on the Center have appeared in many magazines, newspapers, and journals and on local television.

Two series of publications have been initiated, one of Technical Papers from research initiatives, and the other of miscellaneous publications, including materials presented at NCGIA-sponsored workshops. (See also the Initiative and Education sections of this report.)

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. The current members of the Board are:

John E. Estes (University of California), Chair
Robert T. Aangeenbrug (Association of American Geographers)
Vincent P. Barabba (General Motors Corporation)
John R. Borchert (University of Minnesota) (*Member, National Academy of Science*)
John D. Bossler (Ohio State University)
Jack Dangermond (ESRI)
Herbert Freeman (Rutgers University)
John Garver (National Geographic Society)
Patrick E. Mantey (University of California, Santa Cruz)
D. David Moyer (University of Wisconsin-Madison)
Franco P. Preparata (University of Illinois at Urbana)
Chester R. Richmond (Oak Ridge National Laboratory)
John R. Rosati (TRW)
Gerard Rushton (University of Iowa)
G. William Skinner (Stanford University) (*Member, National Academy of Science*)
Lowell E. Starr (U.S. Geological Survey)
Shelby G. Tilford (NASA)
M. Gordon Wolman (Johns Hopkins University) (*Member, National Academy of Science*)

Invitations have been extended to three women to be members of the Board of Directors. One has declined; the other two have the invitation under consideration. Members of the Board and the management of the Center are also actively seeking distinguished minority representation on the Board.

The first two members of the Board were held in Santa Barbara (December, 1988) and Buffalo (June, 1989). The next two meetings will be held in Santa Barbara (December, 1989) and Orono (June, 1990).

Executive Committee. The Executive Committee is made up of the Co-Directors and Associate Directors. Co-Directors Michael F. Goodchild (Santa Barbara) and David S. Simonett (Santa Barbara) are responsible for overall management of the Center. Associate Directors Terence R. Smith (Santa Barbara), Ross D. MacKinnon (Buffalo), and Andrew U. Frank (Maine) are responsible for operations at the three sites.

The Executive Committee meets four times per year. In Year One, three meetings and a teleconference with an agenda were held.

Science Policy Committee. The Science Policy Committee is comprised of the Executive Committee and representatives from Buffalo (Barbara Buttenfield) and Maine (Kate Beard), as well as Waldo R. Tobler (Santa Barbara, NCGIA Senior Scientist) and David M. Mark (Buffalo, Chair of the Committee). This committee is responsible for research policy and meets twice yearly (December and June).

Space. Dedicated space is being allocated at each of the three sites. At Santa Barbara, the Center moved into a dedicated facility of 1800 square feet (renovated by the University) in September 1989. The University of California, Santa Barbara, has also committed funds for renovation to create a specialized GIS teaching laboratory of about 1200 square feet (22 work stations), to be completed July-August 1990, and for renovation of a facility of about 800 square feet to be used for advanced computer cartography/GIS courses, also to be completed July-August 1990. At Buffalo, the Center will move in December 1989 into 5000 square feet of dedicated space renovated by the University at Buffalo. At Maine, plans are in place for a new building of 16,000 square feet funded by the University. This building will be shared by the Center and the Department of Surveying Engineering and will be completed in 1991.

e   Comments on the Appendices.

Three appendices accompany this report. Appendix I is a Center-wide list of publications which fall within the Center's mandate. The publications are presented in several groups: 1) those published in refereed journals and refereed conference proceedings, 2) books, 3)chapters in books, 4) conference proceedings, non-refereed journals, and unrefereed notes in refereed journals, 5) book and software reviews, 6) reports and other miscellaneous unrefereed materials, and 7) articles submitted and under consideration by refereed journals. Readers seeking publication lists for each site of the Center should write to the Santa Barbara site.

Appendix 2 is a list of conferences attended and visits to other institutions made by Center participants. In the interests of space, no details are given concerning papers presented, numbers of attendees, etc. Such details may be found in the individual quarterly reports of each site.

Appendix 3 is a list of the institutions from which visitors came to one or more of the Center sites. Again in the interests of space, only the institutions are given, in a consolidated Center-wide list. No information is provided on the number of visitors or the topics discussed during the visits. Details may again be found in the quarterly reports issued by each site.

3. EXTRAMURAL SUPPORT.

a. Grants and Contracts Awarded as of 11/30/89.

The following is a list of the NCGIA-related grants and contracts awarded to NCGIA personnel as of 11/30/89:

CALIFORNIA STATE DEPARTMENT OF FORESTRY AND FIRE PROTECTION: "Use of Vegetation Maps and Geographic Information"; $39,001; 6/15/89-3/30/91. PIs: Goodchild and Davis.

CALIFORNIA STATE DEPARTMENT OF WATER RESOURCES: "Estimating Drought Probabilities in California Using Tree Rings"; $42,418. PIs: Michaelsen and Loaiciga.

DIGITAL EQUIPMENT CORPORATION: "Object-Oriented Integrated Information System Design"; $200,000; 9 months. PIs: Frank and Egenhofer.

FEDERAL EXPRESS: "Route Planning for Overnight Parcel Deliveries"; $16,500; 9/l/89-8/31/90. PI: Batta.

LAWRENCE LIVERMORE NATIONAL LABORATORY: "Design and Implementation of an Object-Oriented Data Model for Very Large Spatial Data Bases"; $15,000; 7/l/89-6/30/90. PI: Smith.

M AND T BANK (MANUFACTURERS AND TRADERS TRUST COMPANY): "Locational Analysis of Bank Retail Functions"; $4,500; 8/89-12/89. PI: Densham.

MAINE STATE BUREAU OF HEALTH: To develop proposals for GIS applications for the Cancer Registry and Division of Disease Control; $2,400. PIs: Beard and Duchesneau.

NASA: "Development of Practical Cost-Effective Methods Utilizing Satellite Data for Forest Resources Management"; $254,779; two years. PI: Steven Sader; group includes Ehlers.

NSF: "Presidential Young Investigator Award"; $192,000; 6/86-6/91. Rogerson. (Award was extended; the combined value of this award with the private sector match was $100,000.)

OAK RIDGE NATIONAL LABORATORY and MARTIN MARIETTA: "Symposium on the Design and Implementation of Large Spatial Data Bases"; "$4,000. PI: Smith.

OHIO STATE CENTER FOR MAPPING: "Automated Control Point Extraction from Digital Image Data"; $14,955 (seed grant). PI: Ehlers.

QUATERNARY INSTITUTE: "Study of Glacier Movement from Digital Landsat MSS Data"; $9,000. PI: Ehlers.

SEA GRANT COLLEGE PROGRAM: Joint project on Marine GIS with Sea Grant Office; $8,000. PI: Ehlers.

SYRACUSE UNIVERSITY (DEPARTMENT OF GEOGRAPHY): "Symposium: Towards a Rule Base for Map Generalization"; $4,000. PI: Buttenfield.

TOWN OF AMHERST: "GIS Requirements Study"; $3,000; 6/9/89-8/15/89. PI: Calkins.

UNIVERSITY OF CALIFORNIA PACIFIC RIM RESEARCH PROGRAM: "Exploratory Development Workshop"; $13,300; 7/l/89-6/30/90; PI: Appelbaum, Couclelis, and Anselin.

U.S. BUREAU OF THE CENSUS: Internship agreement; $6,000 (NCGIA $3,000; Census $3,000). A Buffalo Ph.D. student worked in Washington, D.C., during summer 1989 on a Multiple Representations (I-3) project. PI: Buttenfield.

U.S. BUREAU OF THE CENSUS: "Lattices for GIS II"; $29,170. Pls: Franzosa and Frank.

U.S. ENVIRONMENTAL PROTECTION AGENCY: "EPA Remote Sensing and Geographic Information System Technology Demonstration Project"; $249,761. PIs: Estes and Scepan.

U.S. GEOLOGICAL SURVEY: "Accuracy of Spatial Data Bases"; $52,100; 8/1/89-2/28/90. PI: Goodchild.

U.S. GEOLOGICAL SURVEY: "Automatic Methods for Cartographic Line Distinction"; $35,885; 9/89-8/90. PI: Buttenfield.

U.S. GEOLOGICAL SURVEY, WATER RESOURCES DIVISION: "GIS for Groundwater Management"; $46,084. PI: Beard.

U.S. GEOLOGICAL SURVEY: "Symposium on the Design and Implementation of Large Spatial Data Bases"; $10,000. PI: Smith.

WILD LEITZ CANADA: "Map Data Overlay and Error Treatment"; $42,432; two years. PI: Beard.

b Equipment and Software Grants Awarded

The following equipment and/or software grants have been awarded to the sites of the NCGIA:

APPLE COMPUTER, INC.: One MAC II computer and a LaserWriter to Maine. PI: Frank.

DIGITAL EQUIPMENT CORPORATION: Advanced Service Delivery System. $200,000 (9/89-7/90) to Maine. PI: Frank.

ESRI: One ARC/INFO LAB Kit, including software, 10 hardware keys, manuals, instruction, workbooks, and video, to both Maine and Santa Barbara. PIs: Frank, Goodchild.

IBM: "Joint Study- Proposal"; hardware and software, to Santa Barbara. Circa $2,300,000. PIs: Simonett, Goodchild, Smith.

INTERGRAPH CORPORATION: Two InterPro 340 workstations with 48mb RAM and 156mb hard disk each, to MaineJ. Includes maintenance on the donated and purchased equipment. $165,000. (The University of Maine has also contributed $25,000 towards this grant and will support two teaching assistant positions in order to make optimal use of the facility, now known as the Intergraph Lab. The installation includes the TIGRIS software package.). PI: Ehlers.

PRIME COMPUTERS: Copies of SYSTEM 9 GIS for the SUN workstations in the Geographic Information and Analysis Laboratory at Buffalo. No cost for acquisition of maintenance. At educationally-discounted prices, 5 copies of SYSTEM 9 would cost $120,000. PIs: Calkins, Densham, Buttenfield, MacKinnon.

SUN MICROSYSTEMS: Five workstations to Buffalo. $139,160 (list)/$99,400 at best educational discounts. PIs: Calkins, Densham, Buttenfield, MacKinnon.

APPENDICES

APPENDIX I
PUBLICATIONS

*Asterisked items specifically acknowledge NCGIA support.

1.1   Articles published or formally accepted in Refereed Journals and Refereed Conference Proceedings:

Abel, D. J., and **Mark, D. M**. A comparative analysis of some 2-dimensional ordering. *International Journal of Geographical Information Systems*, in press. (1989)

Amrhein, C. The effect of problem size in microsimulation modelling using a hybrid model. *Geographical Analysis*, 21, 350-358. (1989)

Anselin, L. "What is special about spatial data? Alternative perspectives on spatial data analysis." *Spatial Statistics*, Past, Present and Future, edited by Daniel A. Griffith, Institute for Mathematical Geography Monograph Series, Ann Arbor, Michigan, In press. (Also NCGIA Technical Paper 89-4) (1989)

Armstrong, M. P., and **Densham, P. J**. Database organization alternatives for spatial decision support systems. *International Journal of Geographical Information Systems*, in press. (1989)

Batty, M. J., **Fotheringham, A.S.,** and Longley, P. A. Urban Growth and Form: Scaling, Fractal Geometry and Diffusion-Limited Aggregation. *Environment and Planning A*, in press. (1989)

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Egenhofer, M. and **Frank, A.U.**: "PANDA: An extensible DBMS supporting object-oriented software techniques", Database Systems in Office, Engineering and Science, Zurich, in: T. Haerder (ed.), *Informatik-Fachbenichte*, Vol. 204, pp. 74-79. March (1989)

Egenhofer, M. and **Frank, A.U**: "Towards a Spatial Query Language: User Interface Considerations", in: D.DeWitt and F. Bauchilar (eds.), *14th International Conference on Very Large Data Bases*, Long Beach, CA, pp 124-133. (1988)

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APPENDIX 2
CONFERENCE PARTICIPATION, TALKS, AND VISITS
BY NCGIA PERSONNEL

A. ATTENDANCE AT CONFERENCES OR WORKSHOPS
**(Usually with papers presented, participation in panels, sessions
chaired, or committee activities. Multiple attendees not indicated.)**

AAAS Conference (San Francisco)
AAG (Baltimore)
AAG Applied Geography Conference/Middle States Division Meeting (Binghamton, New York)
AAG East Lakes Division meeting
AAG Middle States Division
ACSM/ASPRS Fall Convention (Virginia Beach, Virginia)
AM/FM Conference
Applied Aquaculture Workshop (Galway, Ireland)
Applied Geography Conference (Binghamton, New York)
ARC/INFO Users Conference (Palm Springs, California)
ASPRS-ACSM Annual Meeting
Atlantic Institute Research Seminar (University of Maine)
AUTO/CARTO 9
BLM/ISI Meeting (Washington, D.C.)
California Mapping Conference (San Jose, California)
Canadian Cartographic Association (Halifax, Nova Scotia)
Canadian Regional Science Association Annual Meeting (Quebec City)
CD-Rom Workshop (UC Berkeley)
Cognitive Science Society Eleventh Annual Conference (Ann Arbor, Michigan)
Concepts, Development and Applications of GIS Technology (M6rida, Venezuela)
Conference on Data Management for Global Change (University Center for Atmospheric
  Research, Baltimore)
Conference on Use of Computers in Local Mapping (Augusta, Maine)
Consortium of Social Science Associations Congressional Breakfast (Washington, D.C.)
Deutsche Forschungsgcsellschaft Symposium (Wurzburg, Federal Republic of Germany)
DGPF Annual Meeting (Braunschweig, Federal Republic of Germany)
Directions in GIS Research: A CSIRO Perspective (Australian Urban and Regional Information
  Systems Association, Canberra [AURISA])
EPA Great Lakes GIS Workshop
ESRI Users Conference
Executive Roundtable on GIS Data Sharing in Local Government (Orlando, Florida)
First International Conference on Principles of Knowledge Representation and Reasoning
  (Toronto)
Fifth New York State Geographic Information Systems Meeting (Amherst, New York)
First Joint Archaeological Congress (Baltimore)
First Midlands GIS Lecture (Leicester, U.K.)
Friday Harbor Meeting: GIS in Pacific Northwest
GIS National Conference: Challenge for the 1990s (Ottawa, Canada)
GIS/LIS '88 (San Antonio)
Global Change Technology Initiative Workshop (May 1989)
IBM Higher Education Executive Conference

IGARSS Technical Program Committee Meeting (Vancouver, Canada)
IGIS Symposium (Baltimore)
Institute of British Geographers Annual Meeting 1989 (Coventry, England)
Institute of Mathematical Statistics, Western Regional Meeting
International Cartographic Association (ICA) Fourteenth Congress (Budapest)
International Geoscience and Remote Sensing Symposium (IGARSS '89; Vancouver, Canada)
Joint National Meeting of the Canadian Operations Research Society/Institute of Management
    Sciences/Operations Research Society
Land Information Systems Modeling Workshop (University of Melbourne, Australia)
LIS for Local Government Workshop (University of Melbourne, Australia)
MacWorld Exposition (Boston)
Meeting of New Hampshire Land Surveyors (Durham, New Hampshire)
Meeting on Digital Video Applications of Landmark Applied Technologies (Bucksport, Maine)
National Institute of Standards and Technology Information Management Directions 5 (Fort
    Lauderdale, Florida)
NCGIA/NSF/NASA/USGS Meeting (Washington, D.C.)
NEARSS (Northeast Area Remote Sensing System) Annual Meeting (New London,
    Connecticut)
NEARSS/Maine Remote Sensing Interest Group (University of Maine)
Neural Networks for Computing (Snowbird, Utah)
North American Regional Science Meetings (Toronto, Santa Barbara)
Population Association of America (Baltimore)
Regional Science Association Annual Meeting
Sea Grant College Program (Policy Advisory Committee Meeting)
Second International Conference on Data and Knowledge Systems for Manufacturing and
    Engineering
Second International Workshop on Object-Oriented Database Systems (Bad Muenster, Federal
    Republic of Germany)
Second Latin American Conference on Geographic Information Systems Technology (Mdrida,
    Venezuela)
SIGGRAPH '89 (Boston)
Sistemas de Informaci6n Geogrdfica (Caceres, Spain)
Sixth European Colloquium on Quantitative and Theoretical Geography (Chantilly, France)
Surveyors Conference (Pennsylvania State University)
Symposium on Artificial Intelligence and Intelligent Tutoring Systems (University of Maine)
Symposium on the Design and Implementation of Large Spatial Databases (Boston)
Third International Conference on Foundations of Data Organization and Algorithms (Paris)
Third International Symposium on Spatial Data Handling (Sydney, Australia)
Third World Congress of the Regional Science Association (RSA) (Jerusalem)
TIGER Workshop (RAND, Santa Monica, California)
TIGER Geographic Workshop on State Census Data (Santa Barbara)
URISA Conference (Boston)
U.S. Army Symposium on Artificial Intelligence Research for Exploitation of the Battlefield
    Environment (El Paso)
U.S. Geological Survey Conference (September)
U.S. Geological Survey Sioux Falls Meeting on IGBP Global Change Test Site
U.S. Geological Survey/Census Bureau/SORSA Symposium on Geographic Data Structures
    (Airlie, Virginia)

USA-Republic of China and Republic of China-USA Economic Council Twelfth Joint Business Conference (Taipei, Taiwan, R.O.C.)

USENIX Technical Conference and Exhibition (Baltimore, Maryland)

Western Regional Science Association (San Diego, California)

Workshop on Managing the Risks and Recovering the Costs of Geographic and Facilities Management Systems (University of Wisconsin)

Workshop on Spatial Sampling (Environmental Protection Agency/Oregon State University, Corvallis, Oregon)

Workshop on Specification and Prototyping Languages (Bass Harbor, Maine)

Workshop on Teaching of GIS (Ohio State University)

Participation in NCGIA-sponsored conferences and workshops

B. PAPERS OR PANEL PRESENTATIONS CENTERED ON THE NCGIA
(Multiple attendees not indicated.)

AAG (Annual Meeting of the New England/St. Lawrence Valley chapter; Boston)
AAG Applied Geography Conference/Middle States Division Meeting (Binghamton, New York)
Applied Geography Conference (Binghamton, New York)
ARC/INFO Users Conference (Palm Springs, California)
AUTO-CARTO 9
Ball State University
Briefing on the NCGIA for Social Science Agencies (National Science Foundation)
Canadian Cartographic Assoc i ati on/Canadi an Institute for Surveying and Mapping (Halifax, Nova Scotia)
Educational Leadership Conference for County Superintendents of Education, State of California (Santa Barbara)
Environmental Protection Agency (Corvallis, Oregon)
Forty-Fourth New England Management Institute
Geographic Information Systems Conference (Washington, D.C.)
GIS in Higher Education (Ohio State University)
GIS National Conference '89 (Ottawa)
GIS/LIS '88 (San Antonio)
IGIS Symposium (Baltimore)
Indiana University
International Geographic Information Systems (IGIS) Symposium (Baltimore)
ISPRS Workshop on Geographic Information System Theory (Wageningen, Holland)
Maine Development Council Meeting
Michigan State University
National Science Foundation (Washington, D.C.)
Topographic Application of SPOT Image Data (Sherbrooke, Quebec, Canada)
University of Cincinnati
University of Michigan
Urban and Regional Information Systems Association (URISA) Annual Conference (Boston)
Other campus departments, offices, and related groups at each site.

C. NCGIA VISITS (INCLUDING TALKS) TO OTHER INSTITUTIONS
(Multiple visits not indicated.)

Agency for International Development
Apple Computers (Cupertino, California)
Apple Computers (Vienna, Austria)
Aroostook County Bar Association and Crown Chapter of Land Surveyors (Maine)
AURISA (South Australia section)/Prime Computer of Australia, Ltd.
Australian Defense Forces Academy (Canberra)
Ball State University
Battelle Human Affairs Research Center (Seattle)
Baxter State Park (Maine)
Bell Laboratories (New Jersey)
California State Census
California State Resources Agencies
Central Michigan University
Clark County (Nevada)
CSIRO Centre for Spatial Information Systems (Canberra)
Department of Scientific and Industrial Research of New Zealand (met in U.S.)
Department of Transportation Planning, Ajuntement of Barcelona (Spain)
Department of Urban Planning, Ajuntement of Sabedell (Spain)
Digital Equipment Corporation (Boston)
Division of Disease Control, Bureau of Health
Environmental Protection Agency (Corvallis, Oregon)
Environmental Protection Agency (Las Vegas)
ERDAS (Atlanta)
Erie and Niagara Counties (Regional Planning Board)/PRIME Computer, Inc.
ESRI (Redlands, California)
ETH Zurich
George Washington University
Hewlett Packard
IBM Research Center (Palo Alto)
IBM University and College Systems
Indiana University
Institute for Market and Social Analysis (Toronto)
Intergraph Corporation (Reston, Virginia)
ITC (Netherlands)
Jet Propulsion Laboratory
Kent State University
Kork Systems (Bangor, Maine)
Landata, Inc. (Houston)
Landmark Applied Technologies
Little Egypt, Illinois, Regional Planning Commission
Lockhead Co. (Fairfax, Virginia)
Los Alamos National Laboratory
Los Angeles County
Louisiana State University
Maine Science and Technology Commission

Maine State Planning Office
McDonnell-Douglas (Long Beach, California)
Michigan State University
NASA (Ames)
National Geodetic Survey
National Science Foundation
NCGA/URISA Executive Roundtable on GIS Data Sharing in Local Government (Orlando, Florida)
NOAA National Ocean Survey
Oak Ridge National Laboratory
Ohio State University
Panamerican Center for Geographical Studies and Research (Quito, Ecuador)
Regional Research Laboratory, University of Leicester (U.K.)
Regional Research Laboratory, University of Wales (Cardiff)
Rochester Institute of Technology
Rome (New York) Air Developmental Center
Sea Grant College Program in the Northeast at MIT
Southern Illinois University (Carbondale, Illinois)
State Mapping Agency of Catalufla (Spain)
State of Indiana
Statistics Canada Lecture Series (Ottawa)
Stennis Space Laboratory
Sun Microsystems
SUNY (Albany)
SUNY (Stony Brook)
SUNY (Syracuse)
SUNY Research Foundation (Albany)
Swedish Cartographic Society (Stockholm)
Syracuse University
Technical University of Vienna (Austria)
Tektronics
The Island Institute (Rockland, Maine)
TYDAC Technologies (Ottawa, Canada)
Ultimap Corporation/Apollo Computer, Inc.
UNEP/GRID (Geneva)
UNEP/Nairobi
University of California, Los Angeles
University of Connecticut (Storrs)
University of Darmstadt (Federal Republic of Germany)
University of Delaware
University of Edinburgh
University of Hannover (Federal Republic of Germany)
University of Hawaii at Manoa
University of Iowa
University of Lund (Sweden)
University of Maryland
University of Melbourne
University of Michigan
University of New South Wales (Australia)

University of Otago (New Zealand)
University of Queensland (Australia)
University of Stockholm
University of Stuttgart (Federal Republic of Germany)
University of Vienna
University of Wales Institute of Science and Technology (Cardiff, Wales)
University of Washington
University of Wisconsin (Madison)
University of Zurich (Irchel)
U.S Geological Survey
U.S. Bureau of the Census
U.S. Embassy (Bonn, Federal Republic of Germany)
U.S. Fish and Wildlife Service, National Wetlands Inventory
Virginia State University
Wavefront Technologies (Santa Barbara)
World Bank (Washington, D.C.)
World Bank (New York), Water and Urban Development Division
Zycor, Inc. (Austin, Texas)
Other campus departments, offices, and related groups at each site.

APPENDIX 3
VISITORS TO NCGIA SITES
(Multiple visits not indicated.)

Andersen Consulting Co. (Arthur Andersen and Company)
Apple Computer, Inc.
Arkansas Department of Archaeology
Bangor *Daily News*
Barcelona University (Spain)
Bigelow Laboratory for Ocean Sciences
Birkbeck College (University of London)
Boston University
Buffalo Crushed Stone Corporation
California Department of Forestry
California State Census Data Center
California State Department of Transportation
Canada Centre for Mapping (Ottawa)
Canadian American Center
Center for Governmental Research (Rochester, New York)
Chinese University of Hong Kong
Command System (Torrance, California)
CSIRO Division of Building, Construction and Engineering (Victoria, Australia)
CSIRO/Melbourne (Australia)
Curtin University of Technology (Perth, Western Australia)
De Dorschkamp Research Institute for Forestry and Urban Ecology
Decision Technologies (Saugus, California)
Department of Community and Economic Development
Department of Geographic Information (Queensland, Australia)
Digital Equipment Corporation
Erie County (New York) Soil Conservation Service
Erie/Niagara County Regional Planning Board
ESRI (Redlands, California)
ETAK and Software AG
Filial de Petroleos de Venezuela
German Aerospace Research Establishment (DLR)
Global Change Task Force (U.S. Senator Mitchell)
Government of India, Office of the Registrar
Government of South Africa GIS Research Agency
Hunter College, City University of New York
IBM
Indian Institute of Management (Bangalore)
Institute of Marketing and Social Analysis (Toronto)
Intergraph Corporation
Jackson State University
Karst Institute at Guelin (P.R.C.)
KVS Systems (Amherst, New York)
Landmark Applied Technologies (Bucksport, Maine)
Los Angeles County Department of Registrar
Louvain-la-Neuve University (Belgium)

M & T Bank
Maine Development Foundation (legislative tour group)
Map/Info
McMaster University
Moscow State University (U.S.S.R.)
Mountains Conservancy Foundation (Malibu, California)
National University of Taiwan
Navigation Technologies
New York State Center for Hazardous Wastes
New York State Department of Environmental Conservation
New York State Soil Conservation Service
Oak Ridge National Laboratory
Ohio State University
Polytechnic of East London (U.K.)
PRIME Computer, Inc.
PRIME-Wild GIS (Toronto)
Rand Corporation
Regional Research Laboratory, Liverpool University (U.K.)
Regional Research Laboratory, University of Edinburgh (U.K.)
Regional Research Laboratory, University of Lancaster (U.K.)
Rensselaer Polytechnical Institute
Santa Barbara Research Center
Schofield Brothers, Engineering and Surveying
Spatial Data Research, Inc. (Seattle)
Spatial Research
State University of New York (Binghamton)
State University of New York (Brockport)
State University of New York (Buffalo)
SUN Microsystems
Syracuse University
Taylor and Francis Publishers
Telecom Australia Research Laboratories
Terra-Mar
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U.S. Army Cold Regions Research and Engineering Laboratory
U.S. Bureau of Land Management
U. S. Geological Survey
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