

# UCGIS Geographic Visualization Research Priorities, Revisited

By

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## INTRODUCTION

Many of the major challenges set by the geovisualization community by the original UCGIS Research Agenda have now been embraced and progress has been achieved to varying degrees on most research priority issues. These advances can be attributed to the work accomplished by visualization and application scientists in academia, the government and the private sector, as well as the support of the various funding agencies, such as the National Science Foundation, the National Institute of Health and other Federal as well as non-federal funding organizations. While the UCGIS Agenda has played an important role, it was only part of a larger picture. Developments in visualization from other sciences have informed and advanced geovisualization. Likewise, research advancements in geovisualization have also had impacts, at times profound, throughout the geographical sciences and beyond.

The UCGIS *A Research Agenda in GIScience* published as a book in 2004 (McMaster and Userly) contains a chapter on Geographic Visualization that set forth an agenda for research in the short, middle and long terms (Buckley, Gahegan and Clarke 2004). The UCGIS agenda is broad and general rather than narrow and specific, and it is only now having its primary influence. For example, the USGIS research priorities were used as general guidelines for the National Research Council (NRC 2006) in the development of the National Geospatial-Intelligence Agency research priorities.

In this white paper, we revisit the UCGIS agenda for geographic visualization. Rather than suggesting additions, deletions or modifications, we feel at this point that it may be more constructive to more fully evaluate the impact of the UCGIS research agenda, and to gather together pertinent research priorities and advances from the disciplines and applications areas surrounding and complementing GIScience. We have three reasons for this recommendation:

- 1) The impact of the UCGIS agenda on research directions in geographic visualization is only now becoming evident;
- 2) The UCGIS research agenda should be more closely aligned with respect to other research agendas for visualization that have been proposed in various social and natural sciences, including geography and cartography, and;
- 3) It might be prudent in the future to develop an updated research agenda for visualization in conjunction with some of these other agencies or organizations, such as the International Cartographic Association Commission on Geovisualization and Virtual Environments and the USGS, but that joint effort would first have to be coordinated. An opportunity exists in doing so to raise the level of visibility of the geographic visualization needs inside and outside of GIScience.

One of the risks of waiting to offer an updated agenda is the potential to miss opportunities to influence Federal policy as they arise. An agenda that reflects serious reflection and coordination of efforts would likely have more profound effects on such policies than a hastily updated set of priorities developed in isolation of the efforts and advancements in visualization on various other fronts. Scientific visualization as a whole is considerable more valued and developed than when the original agenda was initiated. It is important to retain and reinforce the interdisciplinary links that visualization methodologies offer between geographic science, and science as a whole.

To that end, we feel it is more expedient at this time to take this opportunity to review for the GIScience community the various research agendas

in visualization and geographic visualization, including their related publications, conferences and workshops, as well as the associated activities planned for the immediate future. The remainder of this document describes these other research agendas and reports, including seminal early reports, more current reports, and reports that will be developed following upcoming events. In the conclusion, we propose some next steps that may be of value for UCGIS in the next couple of years.

## EARLY REPORTS

Most early reports focused more broadly on visualization or scientific visualization than on what has been termed geovisualization. National reports on the state of visualization and the need for significant investment in the creation and development of visually-based knowledge discovery techniques date back almost 20 years. The well-known 1987 National Science Foundation (NSF) Visualization report is regarded by many as marking the birth of modern computer-supported visualization as a field, and certainly had a strong impact on funding priorities (McCormick, DeFanti and Brown 1987). As noted in that report, “Significantly more complexity can be comprehended through Visualization in Scientific Computing techniques than through classical ones” or through the “gigabit bandwidth of the eye/visual cortex system”. The upshot of the report was the panel’s recommendation for a strong new initiative to get visualization tools into “the hands and minds” of scientists and noted the need for visualization researchers to team up with scientists and engineers to solve problems (Johnson *et al.* 2006).

Two years later, a report, sponsored by the Department of Interior (DOE) and NSF, focused on data manipulation and visualization of large-scale datasets (Smith and van Rosendale 1998). In part, this report culminated in the DOE Advanced Simulation and Computer (ASCI) Visual Interactive Environment for Weapons Simulation (VIEWS) program, which “significantly advanced visualization tool development and large dataset visualization methodology” (NVAC 2005).

The 1999 Data Visualization Workshop at the University of Memphis was sponsored by the NSF and the Office of Naval Research (ONR). The participants argued strongly for the need for curated data and characterized tasks; the need for taxonomies and general principles to guide visualization design; and the need for visualization practitioners to collaborate with cognition and perception researchers (Maletic and Shah, 1999). Another issue discussed in this report is the tension between application-specific and general-purpose visualization

design (Johnson *et al.* 2006). The PITAC report on computational science (Reed 2005) emphasized the importance of long-term multidisciplinary and multi-agency efforts and cautioned that despite the great opportunities and needs, universities and the Federal government have not effectively recognized the strategic significance of computational science in either their organizational structures or their research and educational planning (Johnson *et al.* 2006). This report advised that these inadequacies could compromise U.S. scientific leadership, economic competitiveness, and national security.

Many reports document the rapid growth in the quantity and type of information that must be handled in general science (Mount 2004), computational science (Hamann *et al.* 2002), information technology (ISTAG 2004), and in society at large (Lyman and Varian 2003). In all cases, visualization is seen as a possible answer. In addition to the reports, there have been several articles that discuss visualization research challenges (Chen 2005, Hibbard 2004, Johnson 2004, Nielson 1996, Rosenblum *et al.* 1994, Rosenblum 1994.)

None of the above reports focused on the visualization of geographic data; however, an International Cartographic Association commission filled that gap with the development of one of the, if not the first, research agendas specifically for geovisualization.

### *ICA Commission on Visualization and Virtual Environments*

In 1995, the International Cartographic Association approved formation of a Commission on Visualization with a term running through fall 1999 (MacEachren and Kraak 1999). The Commission's initial focus was on the use of dynamic maps (*i.e.*, maps that change in response to user action or to changes in data to which they are linked) to prompt thinking. Work of the initial Commission culminated with publication of a special issue of the *International Journal of Geographical Information Systems* in 1999.

During the 1999-2003 renewed term, the Commission was renamed the Commission on Visualization and Virtual Environments (CoVVEs). During this term, emphasis was placed on:

- 1) Extending the Commission-oriented research agenda developed by the initial Commission on Visualization into a comprehensive, international, multidisciplinary research agenda for geovisualization, and
- 2) Building stronger ties to other disciplines engaged in related work.

This work led in January, 2001 to the publication of a special issue of *Cartography and Geographic Information Science* entitled "Research Challenges in

Geovisualization”, with a review preface and four position papers covering different themes . The four primary themes addressed in this research agenda were:

- 1) *Representation* of geospatial information,
- 2) *Integration* of visual with computational methods of knowledge construction,
- 3) *Interface design* for geovisualization environments, and
- 4) *Cognitive/usability* aspects of geovisualization.

CoVVEs developed a comprehensive research agenda by organizing an international team to address each theme. The research agenda development process is detailed on the commission web site at:

<http://www.geovista.psu.edu/icavis>. Working with lead authors of the four agenda sections, chair and co-chair Alan MacEachren and Menno-Jan Kraak identified four cross cutting challenges that span multiple themes. The four cross cutting themes are:

- 1) To develop the understanding and integrated technologies that make it possible to take advantage of the potential offered by increasingly experiential representation technologies,
- 2) To develop extensible methods and tools that enable understanding of, and insight to be derived from, the increasingly large and complex geospatial data sets becoming available,
- 3) To develop a new generation of geovisualization methods and tools that support group work, and
- 4) To develop a human-centered approach to geovisualization.

The cross-cutting challenges were the primary focus for proposed activities by the Commission for the 2003-2006 term (MacEachren and Kraak 1999). The goals of the Commission for 2003-2004 were directed toward advancing science related to map-based visualization of georeferenced information and to potential applications of that research, with a particular emphasis on the cross-cutting issues identified.

In September 2002, CoVVEs sponsored a workshop titled “Exploring Geovisualization” at City University, London. The four-day workshop “provided the opportunity for experts from a number of disciplines to discuss various aspects of the Research Agenda, share experience and ideas and look to future collaboration” (MacEachren, Kraak and Dykes 2002). The outcomes of the 2002 meeting were recorded and made accessible to the community as a whole through a peer reviewed edited publication that appeared a couple of years later.

In October 2004, the Commission met at the University College in Maryland in conjunction with GIScience 2004 and the UCGIS Summer Assembly for a workshop on “Distributed Geovisualization.” Distributed geovisualization related to geovisualization distributed among components, in space, or among individuals and/or draws upon distributed data resources. At the meeting, a developers workshop was “devoted to demonstrations, presentations, discussion, and sharing focused on recent geovisualization software developments”, and there were geovisualization paper sessions (GISC 2004).

In 2005, the Commission sponsored the publication of *Exploring Geovisualization* (Dykes, MacEachren and Kraak 2005), which reviews and explores the current and future status of geovisualization around the world in various cognate fields of study. This book presents some agenda-like suggestions for further geovisualization research especially in its first and last chapters.

CoVVEs is scheduled to meet in June 2006 in conjunction with AutoCarto 2006 and the UCGIS Summer Assembly. The topic will be “Geovisualization and Visual Analytics”, which is directly related to the National Visualization and Analytics Center (NVAC) report described below. Additionally, a July/August 2006 special issue of the *IEEE Computer Graphics & Applications Magazine* will focus on “Exploring GeoVisualization”, and a number of commission members contributed to this issue. The Commission is considering updating its research agenda for geovisualization, but a plan of action has not been outlined at this point; therefore, there may still exist an opportunity for the UCGIS to collaborate with CoVVEs on the development of this agenda.

## **RECENT REPORTS**

Recent reports embrace more of the issues important to advancing geovisualization research and development, and members of the geovisualization research community can often be found serving on panels and participating in workshops to develop initiatives for outlining broader research agendas in visualization and related areas, such as visual analytics (described below).

### ***National Institutes of Health (NIH) and the National Science Foundation (NSF)***

More than fifteen years after publication of the seminal 1987 report on Scientific Computing by McCormick, DeFanti and Brown, the National Institutes of Health (NIH) and the National Science Foundation (NSF) decided it was time to update

their research agenda for visualization. To that end, they held a two-workshop series, starting in 2004, with the intention of drafting an updated report outlining the immediate and long-range challenges for the discipline of visualization and its many related research areas, topics, and applications.

The September 2004 Visualization Research Challenges Workshop was held on the NIH Campus in Bethesda, Maryland. Workshop panelists helped to outline the achievements in scientific, medical, and information visualization over the past two decades (Johnson, Rheingans, and Munzner 2005). They also began discussions on the future grand challenges for the field found not only in the traditional aspects/applications of scientific and medical visualization, but also in the emerging and developing areas of information visualization, large dataset management, new mathematical foundations, and non-traditional research avenues in perception, artistic representation, interaction, uncertainty, simulation, and other topics that are "out of the mainstream" (Johnson, Rheingans, and Munzner 2005)

In May 2005, the NIH and the NSF held the second workshop in the series, "Visualization Research Challenges" in Salt Lake City. This meeting was intended to "conclude these explorations and deliberations and craft the structure for a report that could serve as a guidebook for future initiatives, outlining the immediate and long-range challenges for the discipline of visualization and its many related research areas, topics, and applications" (Johnson, Rheingans, and Munzner 2005). The workshop culminated in the report titled *NIH/NSF Visualization Research Challenges: January 2006* (Johnson *et al.* 2006).

The goal of the report was to "to evaluate the progress of the maturing field of visualization, to help focus and direct future research projects, and to provide guidance on how to apportion national resources as research challenges change rapidly in the fast-paced world of information technology. In it we describe some of the remarkable achievements visualization enables and discuss the major obstacles blocking the discipline's advancement" (Johnson *et al.* 2006). The findings and recommendations were meant to reflect not only information gathered from visualization and applications scientists during the two workshops, but also input from the larger visualization community. Thus, the report focuses on a broader spectrum of application domains that can benefit from visualization, including health, science, and engineering. Many of the findings and recommendations in their report are echoed in various other reports (Johnson *et al.* 2006).

***National Visualization and Analytics Center (NVAC)***

In 2004, the U.S. Department of Homeland Security (DHS) chartered the National Visualization and Analytics Center (NVAC) with the goal of helping to counter future terrorist attacks in the U.S. and around the globe (NVAC 2005). A major objective for NVAC was to define a five-year research and development (R&D) agenda for visual analytics to address the most pressing needs and to facilitate advanced analytical insight. NVAC, under the sponsorship of the DHS, produced a major book-length report defining the area of *visual analytics*, or “the science of analytical reasoning facilitated by interactive visual interfaces” (Thomas and Cook 2005).

Under the leadership of Pacific Northwest National Laboratory and researchers on the R&D Agenda Panel, a Research and Development Agenda for visual analytics was developed to define the directions and priorities for future research and development programs focused on visual analytics tools. This R&D Agenda, *Illuminating the Path: The Research and Development Agenda for Visual Analytics*, “provides a coordinated technical vision for government and industrial investments, and ensures that a continued stream of technology and tools enter the hands of analysts and emergency responders” (Thomas and Cook 2005). A synopsis of the report was published in the January/February 2006 issue of *IEEE Computer Graphic and Applications* (Thomas and Cook 2006).

The R&D Agenda presents recommendations to advance the state of the art in these four major visual analytics research areas:

- 1) The science of analytical reasoning,
- 2) Visual representations and interaction techniques,
- 3) Data representations and transformations, and
- 4) Production, presentation, and dissemination.

The R&D agenda also includes recommendations to accelerate the development of the most promising research into practice and to set the stage for an enduring visual analytics research community through a combination of education and research collaboration.

A number of workshops spun off from the NVAC report. A June 2005 “Workshop on Visual Analytics” in Darmstadt, Germany was jointly organized by the University of Konstanz and Fraunhofer IGD (Keim, Kohlhammer and Thomas 2005). Experts from the United States and Europe discussed visions and ideas in the emerging field of visual analytics, starting from the NVAC initiative. Although the emphasis in the U.S. is on homeland security among other fields, this is not the focus in Europe where the large number of application areas offers a wider range of opportunities. There is the potential that an over-concentration of research attention and funding on homeland security in the U.S. will cede

research leadership in these parallel parts of the agenda to Europe. The European Union is expected to establish a multidisciplinary research program, combining data mining technology, visualization, and interaction within the 7th Framework Program, the European Union's main instrument for funding research and development (CORDIS 2006).

The concluding panel discussion from the June 2005 workshop led to the identification of their top ten Visual Analytics Research challenges in each of two categories: those dealing with applications challenges and those that are technical challenges. The top ten application challenges are:

- 1) Engineering Analytics
- 2) Software Analytics
- 3) Environmental Monitoring (Climate & Weather)
- 4) Personal Information Management (Vis@Home)
- 5) Physics / Astronomy
- 6) Biology & Medicine / Health
- 7) Mobile Graphics / Traffic
- 8) Business
- 9) Security (Homeland, Network, ...)
- 10) Disaster / Emergency Management

The top ten technical challenges are:

- 1) Problem Solving / Decision Science / Human Information Discourse
- 2) Semantics (including Modeling Semantics)
- 3) Scalability in Problem Size
- 4) Data Streams: Data Compression & Feature Extraction
- 5) Evaluation
- 6) Synthesis of Problems in Applications
- 7) Data Quality / Uncertainty
- 8) Data Provenance
- 9) User Acceptability
- 10) Integration with Automated Analysis, Databases, Statistics, Design, Perception

In July 2005, a Joint ICA Commissions Seminar titled "Internet-Based Cartographic Teaching and Learning: Atlases, Map Use, and Visual Analytics" was held in Madrid, Spain (ICA 2005). The commissions involved were: Education and Training, Cartography and Children, National and Regional Atlases, Maps and the Internet, and Visualization and Virtual Environments, a

clear indication of the cross-cutting power of the Internet and visualization methodologies.

The topic of the 2006 annual meeting of CoVVEs to be held in June 2006 in conjunction with AutoCarto 2006 and the UCGIS Summer Assembly will be “Geovisualization and Visual Analytics” (CoVVEs 2006). The first issue of the 2007 *Cartographica* journal will be a special issue that results from the discussions and deliberations that take place during this event.

The Spring 2006 meeting of the Visualization & Analytics Centers (VAC) Consortium—a partnership with NVAC, industry, university, and government members collaborating to solve national security problems for DHS—will be held at Stanford University May 23-24, 2006. Stanford was the first established Regional Visualization and Analytics Center (RVAC). Speakers from recently announced RVACs (University of Washington, Purdue University, The Pennsylvania State University, University of North Carolina-Charlotte and Georgia Institute of Technology) will detail the mission of their programs and report on initial research projects.

An IEEE Symposium on Visual Analytics Science and Technology (VAST) will be held in October 2006. IEEE VAST 2006 is the first international symposium dedicated to the advances in visual analytics science and technology (VAST 2006). The scope of the symposium, co-located with the annual IEEE Visualization 2006 Conference and the IEEE InfoVis Symposium, is based on the research agenda published in *Illuminating the Path* (Thomas and Cook 2005).

A clear lesson from this valuable research work and agenda setting is that visualization efforts in cartography and computer science are central to any effort conducted within GIScience. UCGIS must engage and interact with these communities, and evaluate what parts of a broad field emerging as “Visual Analytics” are of value to GIScience. UCGIS should then focus on these aspects, and use its integrative capabilities to move the agenda forward selectively, while using advocacy to support the field as a whole, especially with funding agencies.

### ***National Research Council (NRC)***

The National Research Council (NRC) is part of the National Academies, a set of private, nonprofit institutions that provide science, technology and health policy advice under congressional charter with the purpose of furthering knowledge and advising the federal government. The report of the NRC’s Mapping Science Committee on National Geospatial-Intelligence Agency (NGA) research priorities is now published (NRC 2006). NGA has defined their “Top 10 Challenges” for geospatial intelligence (GEOINT), or “the exploitation and analysis of imagery and geospatial information to describe, assess, and visually

depict physical features and geographically referenced activities on the earth” (NGA 2004). Using these research challenges as a base, along with knowledge of the current state of the art in geospatial information science, the hard research problems associated with each of the GEOINT challenges were identified, leading to a total of twelve recommendations. This report leans somewhat on the UCGIS agenda. Table 1 summarizes the ten NGA Research Challenges, their associated Hard Problems and the twelve recommendations. The recommendations are detailed in the report (NRC 2006), which is available on-line.

<b>NGA Research Challenges</b>	<b>Hard Problems</b>	<b>Rec.</b>
(1) Achieve Persistent Tasking, Processing, Exploitation and Dissemination (TPED)	Assimilation of new, numerous, and disparate sensor networks within the TPED process	<b>1</b>
	Spatio-temporal data mining and knowledge discovery from heterogeneous sensor data streams	<b>2</b>
	Spatio-temporal data base management systems	<b>3</b>
(7) Compress Timeline	Process automation and human cognition	<b>4</b>
	Visualization	<b>5</b>
	High performance grid computing for geospatial data	<b>6</b>
(2-6) Exploit All Forms of Imagery (and Intelligence)	Image data fusion across space, time, spectrum, and scale	<b>7</b>
	Role of text and place data integration	<b>8</b>
	Reuse and preservation of data	<b>9</b>
	Detection of moving objects from multiple heterogeneous intelligence sources	<b>10</b>
(8) Share with Coalition Forces, Partners, and Communities at Large	GEOINT ontology	<b>11</b>
(9) Support Homeland Security	Covered by other areas	
(10) Promote Horizontal Integration	Multi-level security	<b>12</b>

The report notes that the NGA Chief Scientist identifies the following disciplines as preeminent in pursuing basic research that is applicable to the NSG strategic intent:

- Geodesy and Geophysics
- Advanced Geoprocessing – including architectures and design, special issues for geospatial/image computation, data mining, advanced Synthetic Aperture Radar (SAR) processing, information technology (IT) for massive data files, mass storage, data bases/structures, visualization, and high-performance computing
- Remote Sensing
- Geospatial-Intelligence Analytics

As can be seen above, the Advanced Geoprocessing basic research includes special issues for geospatial/image computation, data mining, and *visualization*. NGA is heavily committed to visualization research, as is clearly evident not only from its research structure, but also from its University program the NGA University Research Initiative (NURI). From the report, it is evident that a large proportion of the US-based visualization research, particularly geovisualization, is selected and funded by the NGA. However, NGA's needs are somewhat specialized, and in spite of an interest in broader research, a great deal of the research is targeted at GEOINT problems. Thus it could be generally stated that less attention is given to the civilian applications and research issues surrounding geovisualization.

One consequence if the NGA Research report will likely be on NURI. The focus for the FY06 NURI solicitation includes four specific topics supporting Automated Geospatial-Intelligence Analysis (AGA) and its constituent technologies (NURI 2006). This involves research to help improve analyst abilities as well as providing better automated capabilities in the analyst environment. The NURI program awards multi-year grants to address these needs. The four topics for 2006 relate strongly to geovisualization, and include:

- 1) Advanced Mathematical Sensor/Data Exploitation Capabilities and Applications
- 2) Selection, Assignment, and Training of Imagery Analysts
- 3) Geodesy and Geophysics
- 4) New Techniques for Discovery and Analysis

The NRC report may have other impacts, including an influence on funding from governmental agencies.

## **USGS CESIS**

The USGS has commissioned the NRC's Mapping Sciences Committee to conduct a study of its new Center for Excellence in GIScience (CEGIS), specifically targeted at developing a USGS agenda for GIScience. While a report may not be ready for almost a year, much effort will be devoted to a new agenda that will have significant federal impact (USGS 2005). The timing will overlap with any new UCGIS activity, including updating its research agenda. Much of the motivation for the study and for CEGIS come from a USGS long term planning document for Geography research (McMahon *et al.* 2005).

To quote a recent USGS request for post-doctoral students, "Researchers and managers in USGS geography related disciplines are concerned with the need for and requirements of horizontal integration of models (use in different regions) along with vertical integration (use with other models and applications within a single region). More specifically, many researchers are concerned with making models certifiable for multiple users across unique regions and disciplines (horizontal integration) in order to assure the integrity and reliability of results" (USGS 2005). As a result, there is new emphasis on research on spatial modeling, data discovery, pattern identification, visualization, and spatial statistics to help "improve the value of USGS data and provide a basis for assessments of land change processes" (USGS 2005).

Clearly there exists an opportunity for UCGIS to cooperate with and participate in this agenda setting, which is likely to influence national activities. UCGIS should consider formally responding to the NRC report when it reaches the review stage.

## **OTHER EVENTS**

In addition to the reports described above, a number of workshops have or will be convened to discuss visualization and to varying extents geovisualization. Those events are described below.

### ***"Geospatial Visualization and Knowledge Discovery Workshop"***

A three-day "Geospatial Visualization and Knowledge Discovery Workshop", funded through a grant from the Advanced Research and Development Activity (ARDA) and the United States Geological Survey (USGS), was held in November, 2003, at the National Conference Center in Lansdowne, Virginia.

Small groups summarized and reported discussions to the rest of the workshop with the overall objective of prioritizing research for the knowledge discovery and visualization communities (UCGIS 2003).

### *“Toward Improved Visualization of Uncertain Information”*

The Board on Mathematical Sciences and Their Applications held a workshop titled “Toward Improved Visualization of Uncertain Information” in March, 2005 at the National Academy of Sciences in Washington, D.C. (BMSA 2005). A major goal of this workshop was to “convene experts from various communities to share perspectives on these challenges. An additional goal, prompted by the dramatic increase in the size of data sets in many fields over recent years, is to spark increased research into innovative approaches for visualizing uncertainty for large data sets” (BMSA 2005).

### *GEON Visualization Workshop*

The Geosciences Network (GEON) sponsored a visualization workshop that was held in March, 2005 in the new Synthesis Center at the San Diego Super Computing Center (GEON 2005). The goal of the workshop was to examine visualization and data systems developments related to 4D representation of earth science datasets and models in a grid computing environment (Meertens, Baru, and Arrowsmith 2005). The focus was on defining the visualization requirements needed to conduct integrative science, to evaluate what tools are available, and to assess the areas where additional developments are needed. Data discovery, retrieval, standards, and interoperability among visualization packages and in relation to the GEONgrid were also addressed in the workshop. Presentations included a wide range of state-of-the-art visualization tools displayed on the new Synthesis Center wide-screens and stereowall. A summary report from the workshop, “Geon: Cyberinfrastructure for the Geosciences” was published online (Meertens, Baru, and Arrowsmith 2005).

### *Geographic Visualization across the Social Sciences*

In June 2006, a workshop titled “Geographic Visualization across the Social Sciences: State of the Art Review” will be held at the University of Manchester. The goal of the two-day workshop is “to explore the ‘state of the art’ of geographic visualization across the social sciences, reviewing innovative methods and techniques, evaluating new software tools and data resources, and reporting the development of new applications to support research and

pedagogy” (NCeSS 2006). The workshop aims to produce an edited book of papers presented to help define the scope of visualization work in the social sciences. In some senses, the workshop represents a (near) ten year updating of the Advisory Group on Computer Graphics (AGOCCG)-sponsored ‘Graphics, Visualization and the Social Sciences’ workshop held in May 1997 at Loughborough University in Leicestershire, UK (NCeSS 2006).

## CONCLUSION

The occasion of the 2006 UCGIS Summer assembly is the impetus for a reexamination of the UCGIS Research Agenda for GIScience as set forward in the 2004 book (McMaster and Userly 2004). The authors of this white paper are those of Chapter 11 of that book, entitled “Geographic Visualization.” In this revisit we have set forth what we believe is a convincing case that the UCGIS agenda is well advanced. This has come about both because of, and in spite of, the UCGIS agenda setting exercise. Clear from this examination is that geographic visualization from a GIScience perspective cannot be seen in isolation. Important parallel research and agenda setting has taken place in cartography, computer science and in the cognitive study of human-computer interfaces, where a new and highly integrative new emphasis “Visual Analytics” is currently emerging and receiving attention. Furthermore, the visualization and geovisualization needs of specific agencies, among them the DHS, the NGA and the USGS, will become important research drivers, as will needs from other interdisciplinary projects such as GEON. Combined, these thrusts are likely to create a new set of priorities for geovisualization to which the UCGIS must be responsive.

UCGIS should adapt a three pronged strategy for the geovisualization agenda. First, parallel activities (as reviewed here) should be actively followed and reported throughout the UCGIS membership. The GIScience geovisualization research community is not large, so the community tools of e-mail lists, discussion forums, and Wikis can easily keep UCGIS members informed and solicit opinion and consensus when necessary. Secondly, UCGIS members should individually and collaboratively pursue research funds from federal and other agencies using the UCGIS agenda and the UCGIS membership structure as leverage for support. This goal can be met with the same tools as the information goal. Thirdly, the broader scientific visualization research community must be made aware of the special visualization needs and opportunities when geospatial data are involved. To this end, raising the prominence and visibility of UCGIS member institutions research should be a priority. Perhaps making visualization a theme for a summer assembly,

conducting a specialist workshop or conference, or guiding the coordination of innovative research targeted at journal special issues or another book are in order. Ultimately, however, UCGIS GIScientists must participate in a broader set of research conferences, workshops, journals and communities. Failure to do so will result in GIScience simply being left out of the national visualization research agenda.

Above all, the era for agenda setting for the next decade is over. UCGIS has played a role, and an important one, but it is nevertheless only part of a more complex whole. The power of integrative, interdisciplinary science is nowhere more evident than in geovisualization. It is now time to bring together research funding and research talent to advance the agenda. UCGIS's new role should be as promoter and advocate, and the research should come from UCGIS member institutions, ideally working collectively.

On a final note, UCGIS should fully recognize the increased and substantial impact of the private sector on geovisualization research and development. Most of the high impact and broad market geovisualization innovations of the first decade of the twenty-first century have come from outside of University research. Both mass market (e.g. Google Earth, ArcGlobe, Microsoft Virtual Earth and Zillo) and government service sector industries have revolutionized geovisualization yet again. Interoperability, geospatial standards, open systems and institutions advancing the open systems approach have been highly instrumental in this revolution. UCGIS could play an important role in building collaboration between UCGIS members and businesses involved in the geovisualization marketplace. UCGIS should examine and debate how such a partnership could work to the benefit of UCGIS and for the future of GIScience.

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# UCGIS Geographic Visualization Research Priorities, Revisited

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Aileen Buckley, Keith Clarke, and  
Mark Gahegan

# Recommendation

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- Rather than suggesting additions, deletions or modifications...
  - ...more fully evaluate the impact of the UCGIS research agenda, and
  - gather information about other pertinent research priorities and advances
    - from the disciplines and applications areas surrounding and complementing GIScience
-

# Why not revise?

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- ❑ The impact of the UCGIS agenda on research directions in geographic visualization is only now becoming evident;
  - ❑ The UCGIS research agenda should be more closely aligned with other research agendas for visualization that have been proposed in various social and natural sciences, and;
  - ❑ UCGIS should coordinate the development of an updated research agenda in conjunction with other agencies or organizations.
-

# Recommendation

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- Rather than suggesting additions, deletions or modifications...
  - ...more fully evaluate the impact of the UCGIS research agenda, and
  - gather information about other pertinent research priorities and advances
    - from the disciplines and applications areas surrounding and complementing GIScience
-

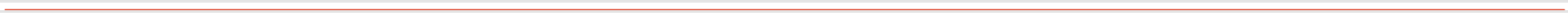
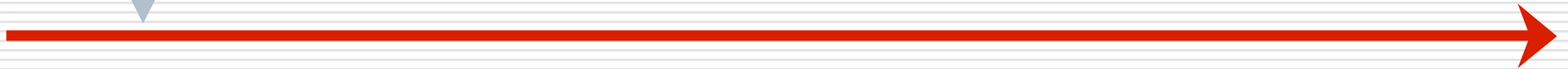
# The foundation

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National  
Science  
Foundation  
(NSF)  
Visualization  
report

*McCormick, DeFanti  
and Brown*

**1987**



# Early activities

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National  
Science  
Foundation  
(NSF)  
Visualization  
report  
*McCormick, DeFanti  
and Brown*

**1987**

Advanced  
Simulation and  
Computer (ASCI)  
Visual Interactive  
Environment for  
Weapons  
Simulation  
(VIEWS) program

**1989**

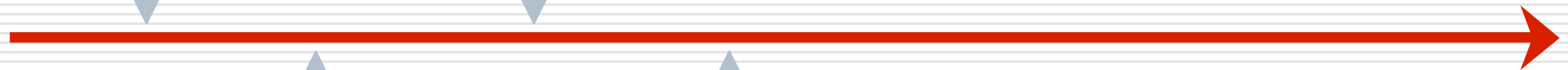
**1989**

Department of  
Interior (DOE) and  
NSF workshop on  
data manipulation  
and visualization of  
large-scale datasets

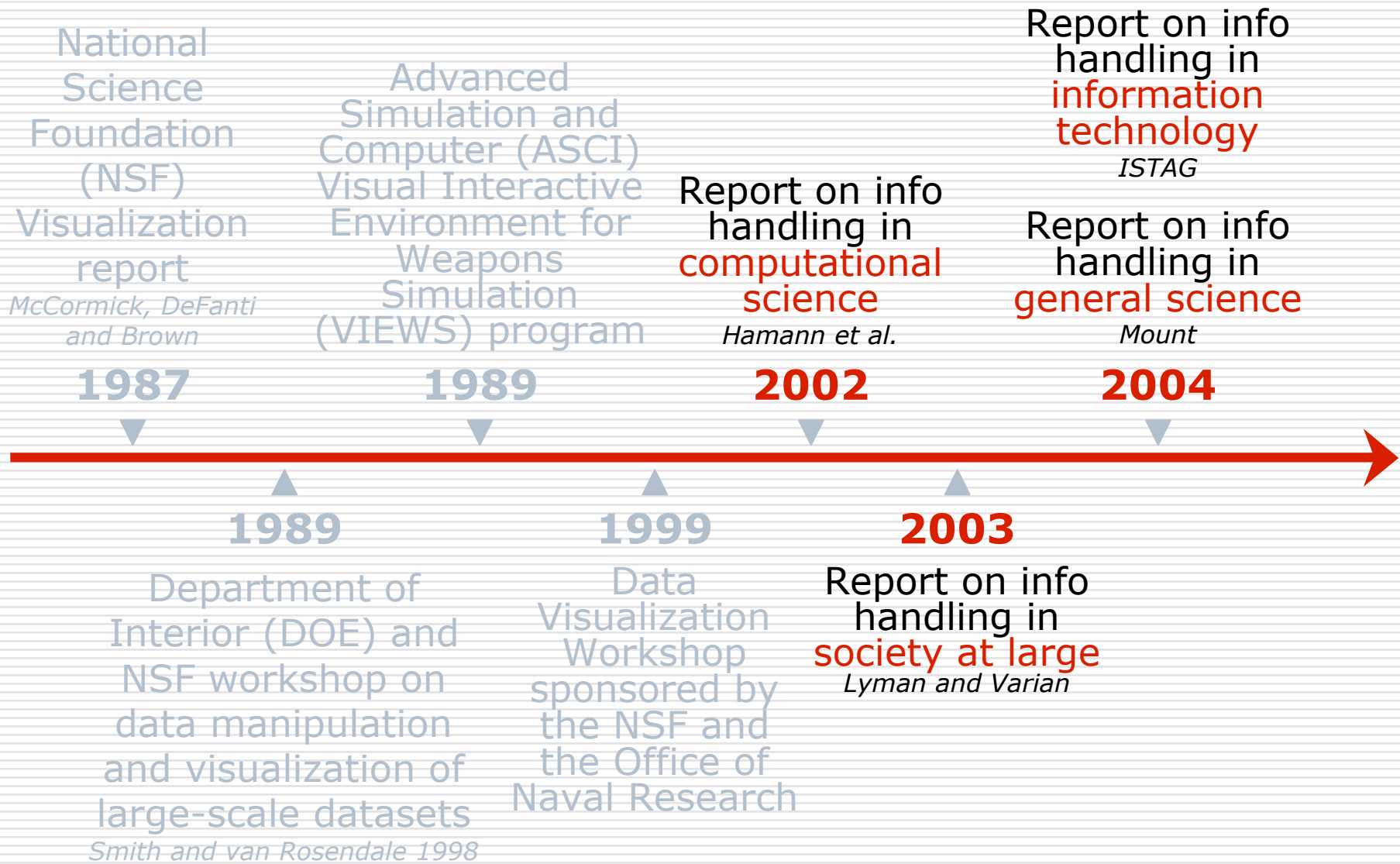
*Smith and van Rosendale 1998*

**1999**

Data  
Visualization  
Workshop  
sponsored by  
the NSF and  
the Office of  
Naval Research

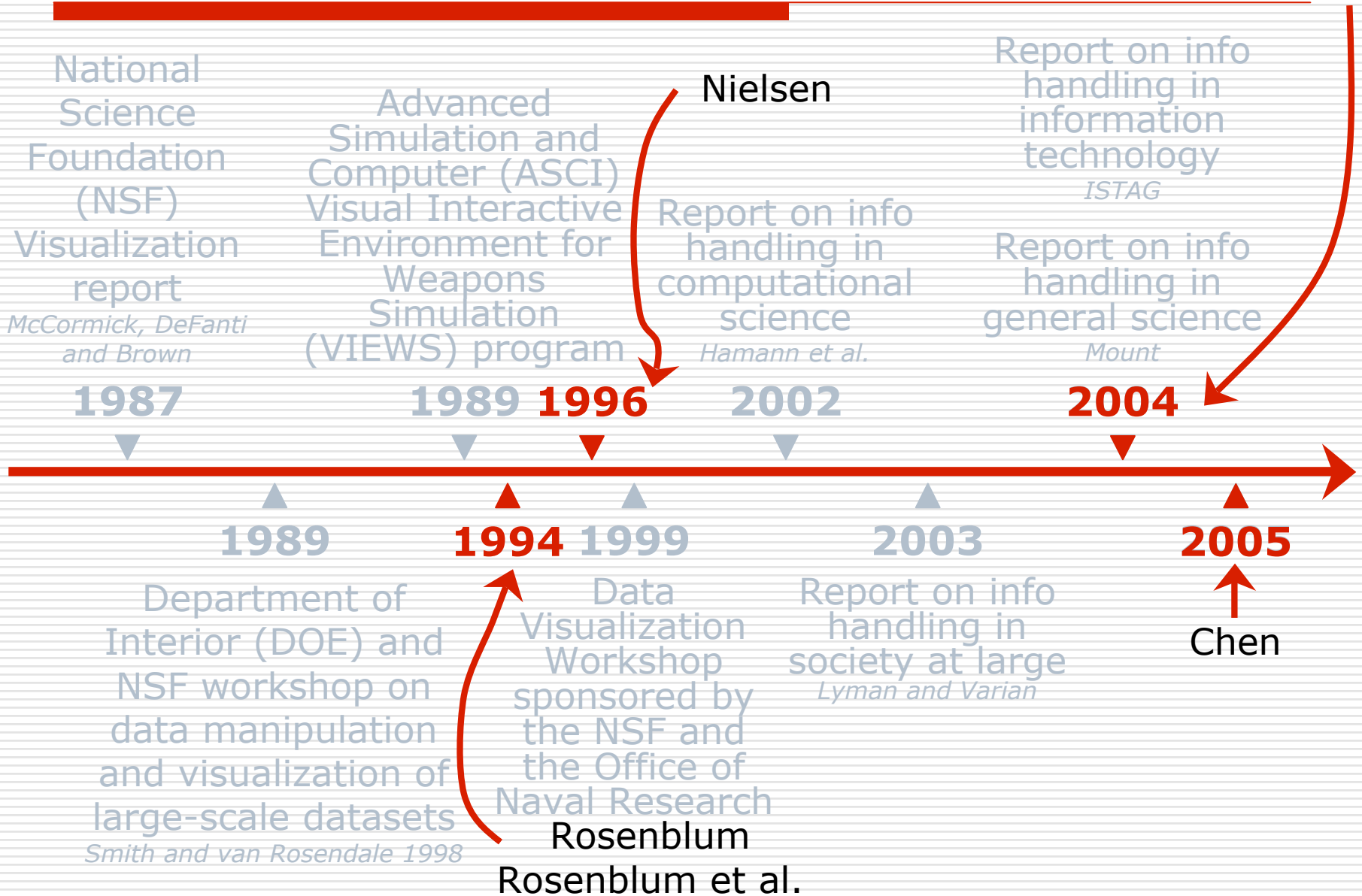


# Information handling reports

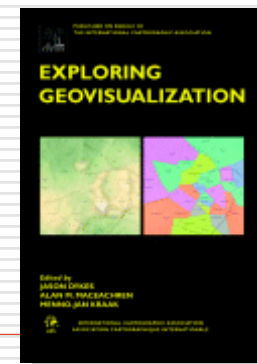
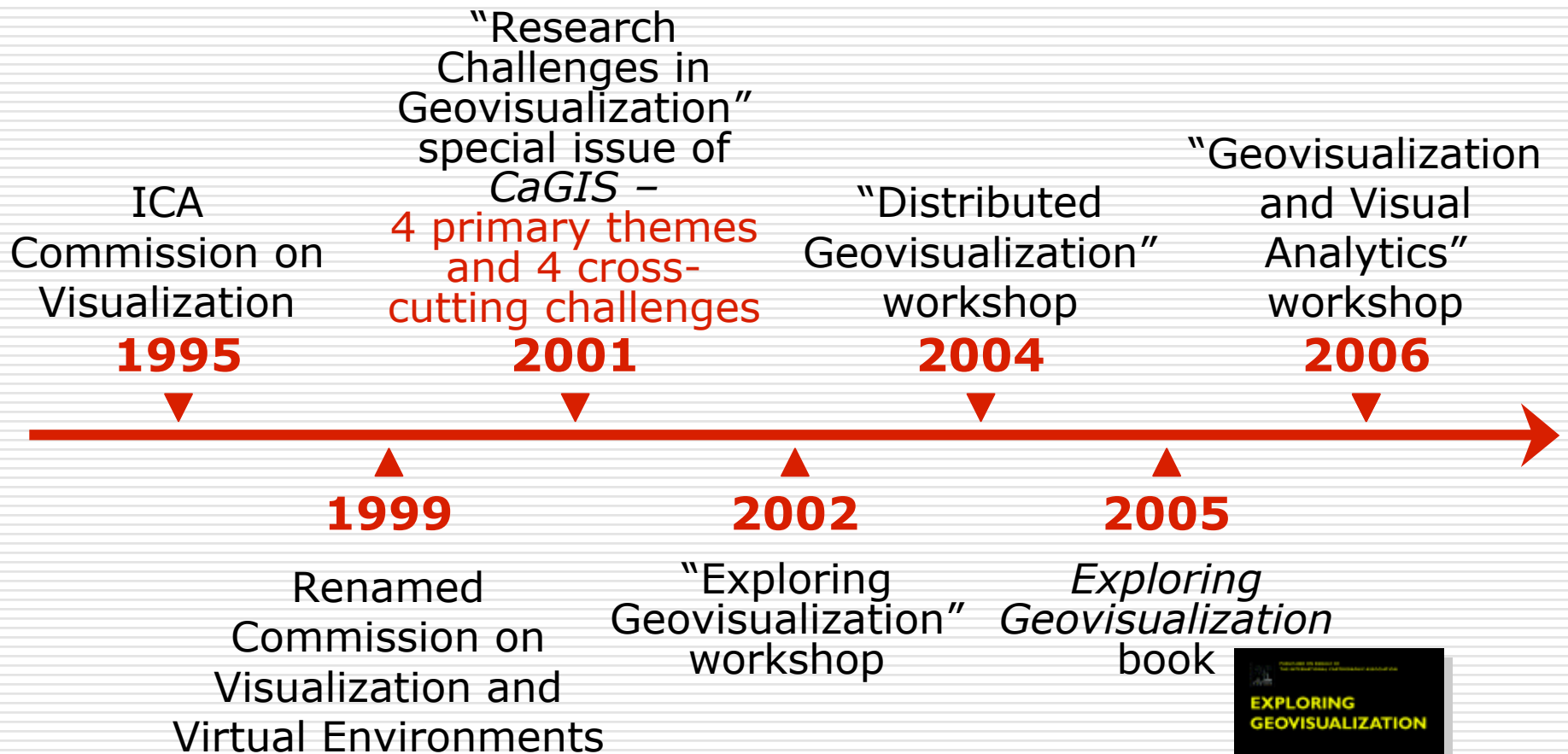


# Articles that discuss vis research challenges

Johnson  
Hibbard



# International Cartographic Association (ICA)

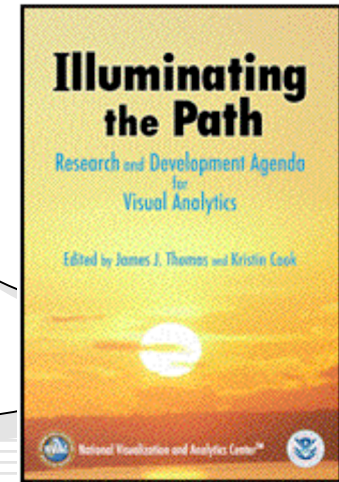


# Other recent activities

National Visual Analytics Center

**NVAC**

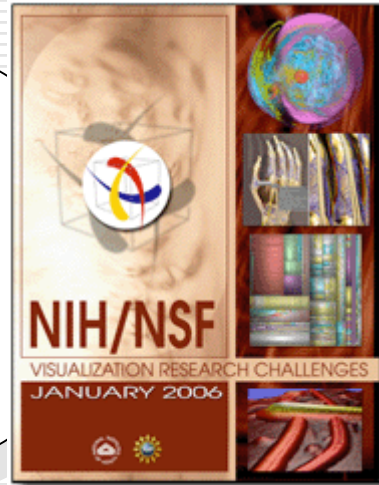
Chartered in 2004



2005

Dept. of Homeland Security (DHS)

**NIH/NSF**



January 2006

2004 workshop

2005 workshop

2006 meeting of the Visualization & Analytics Centers

2006 IEEE Symposium on Visual Analytics S&T

2006 Geovisualization & Visual Analytics Workshop

2005 Joint ICA Commissions Seminar

2005 Workshop on Visual Analytics

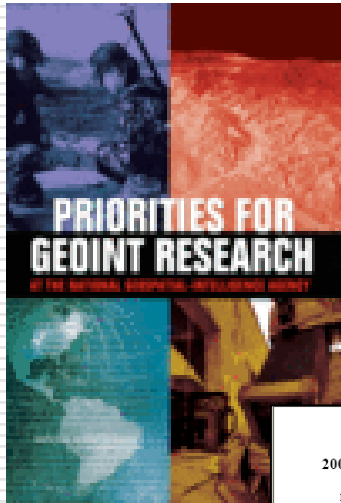
Top Ten Visual Analytics Research Challenges

*Maps and the Internet  
Education and Training  
Cartography and Children  
National and Regional Atlases  
Visualization and Virtual Environments*

*applications challenges  
technical challenges*

# Other recent activities – con't.

## National Research Council (NRC)



2006 National Geospatial-Intelligence Agency  
University Research Initiatives (NURI)  
Broad Agency Announcement (BAA) HM1582-06-BAA-0004

### OVERVIEW INFORMATION

Federal Agency Name: Department of Defense, National Geospatial-Intelligence Agency (NSA), Information Enterprise, Office of Basic and Applied Research

Funding Opportunity Title: 2006 NGA University Research Initiatives (NURI)

Announcement Type: Initial Announcement

Funding Opportunity Number: NGA BAA Number HM1582-06-BAA-0004

Catalog of Federal Domestic Assistance (CFDA) Number: None

Dates: Proposal Due Date is 3 May 2006

Executive Description: This Broad Agency Announcement by the National Geospatial-Intelligence Agency supports a FY06 NGA competition for the NGA University Research Initiative. The focus for the FY06 NURI solicitation includes four specific topics supporting Automated Geospatial-Intelligence Analysis (AGA) and its constituent technologies. This solicitation research to help support analysis objectives in ways providing better command capabilities in the analyst workstream. The NURI program awards multi-year grants to address these needs.

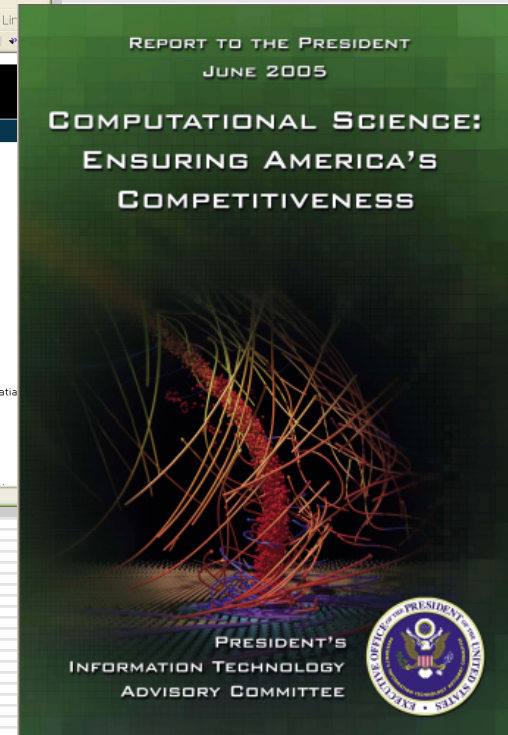
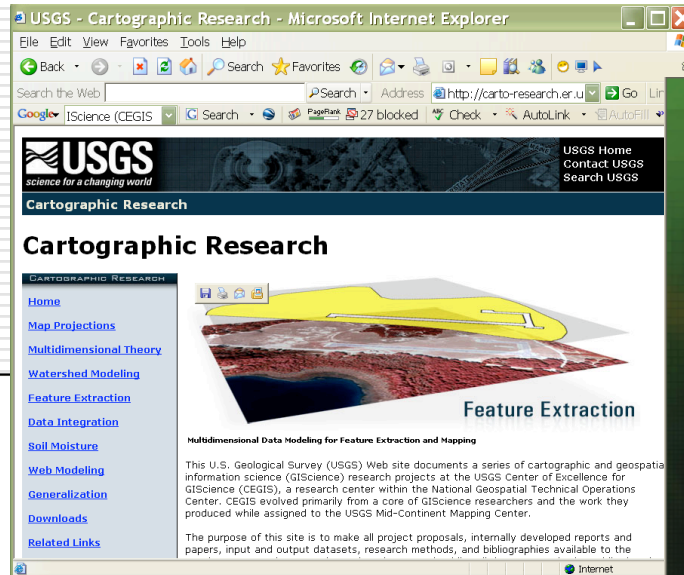
Anticipated Award/Number of Awards: Through this competition, NGA expects to make eight to ten awards in several specific research topics as described below. The level of the grant awards is about \$450,000 for a three-year grant.

Who is Eligible to Apply: A U.S. domestic college, university or other degree-granting institution providing post-secondary school courses of study will be the primary avenue for proposal of award solicitation. This institution must employ the Principal Investigator. NGA also welcomes proposals from Historically Black Colleges and Universities, Hispanic-Serving Institutions, Tribal Colleges and Universities, and other minority institutions, individually or as members of proposed teams. This BAA does not provide a set-aside for funding proposals from minority institutions. However, the parallel NGA NSIC/NSI Research Initiative BAA HM1582-06-BAA-0005 released simultaneously with this one provides for a specific set-aside to minority institutions.

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## NGA University Research Initiative (NURI)

## USGS Center for Excellence in GIScience (CEGIS)



## President's Information Technology Advisory Committee (PITAC) report on computational science

# Others

## Geographic Visualization

"Geospatial Visualization and Knowledge Discovery"  
Workshop - 2003

*Sponsored thru UCGIS by the Advanced Research and Development Activity (ARDA) and United States Geological Survey (USGS)*

Geosciences Network (GEON)  
Visualization workshop - 2005

*Workshop to examine visualization and data systems developments for 4D representation of earth science datasets and models*

"Toward Improved Visualization of Uncertain Information"  
Workshop - 2005

*Workshop to examine visualization and data systems developments for 4D representation of earth science datasets and models*

"Geographic Visualization across the Social Sciences"  
workshop - 2006

*Workshop "to explore the 'state of the art' of geographic visualization across the social sciences"*

# A three pronged strategy

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**1.** Parallel activities should be actively followed and reported throughout the UCGIS membership

*The community is not large; therefore, we can use e-mail lists, discussion forums, and Wikis to inform UCGIS members and solicit opinion and consensus*

**UCGIS Approach**

*This goal can be met with the same tools as the information goal*

**2.** The broader scientific visualization research community must be made aware of the special visualization needs & opportunities when geospatial data are involved

*Use the UCGIS agenda & the UCGIS membership structure as leverage for support*

**3.** UCGIS members should individually & collaboratively pursue research funds from federal & other agencies

# To that end....

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- Raising the prominence and visibility of UCGIS member institutions research should be a priority
    - Visualization as a theme for a summer assembly
    - Conducting a specialist workshop or conference
    - Guiding the coordination of innovative research targeted at journal special issues or another book
  - UCGIS GIScientists must participate in a broader set of research conferences, workshops, journals and communities
    - Failure to do so will result in GIScience simply being left out of the national visualization research agenda
-

# Above all...

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- The era for agenda setting for the next decade is over
    - UCGIS has played an important role, but it is only part of a more complex whole
    - The power of integrative, interdisciplinary science is nowhere more evident than in geovisualization
    - It is time to bring together research funding and research talent to advance the agenda
    - UCGIS's new role should be as promoter and advocate, and the research should come from UCGIS member institutions working collectively
  - UCGIS should fully recognize the increased and substantial impact of the private sector on geovisualization research and development
-

# The end

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## “Next Steps in the UCGIS Research Agenda”

### Topics from:

*A Research Agenda for Geographic Information Science*

Robert McMaster and E. Lynn Usery, 2004, published by Taylor & Francis, distributed by CRC Press

Hyperlinks are to short documents providing 2006 updates to the state-of-the-art on the topic since the 2004 publication of the book.

### [Call for 2006 Summer Assembly: Next Steps in the UCGIS Research Agenda](#)

1. Introduction to the UCGIS Research Agenda
2. [Spatial Data Acquisition and Integration](#)
3. Cognition of Geographic Information
4. Scale
5. Extensions to Geographic Representations
6. [Spatial Analysis and Modeling in a GIS Environment](#)
7. Research Issues on Uncertainty in Geographic Data and GIS-Based Analysis (forthcoming)
8. The Future of the Spatial Information Infrastructure
9. [Distributed and Mobile Computing](#)
10. [GIS and Society: Interrelation, Integration, and Transformation](#)
11. [Geographic Visualization](#)
12. [Ontological Foundations for Geographic Information Science](#)
13. Remotely-Acquired Data and Information in GIScience (forthcoming)
14. Geospatial Data Mining and Knowledge Discovery
15. Postscript on the UCGIS and Research