Investment in geographic information science and remote sensing as a catalyst for expanding interdisciplinary research and education at Arizona State University

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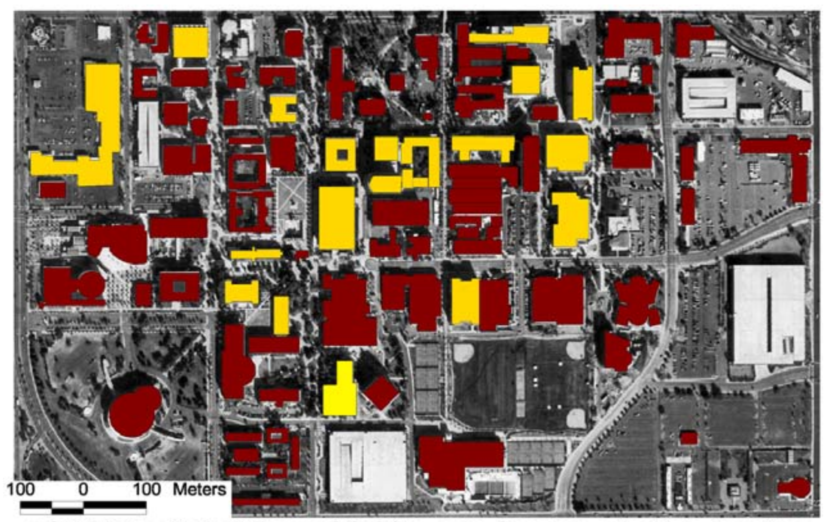
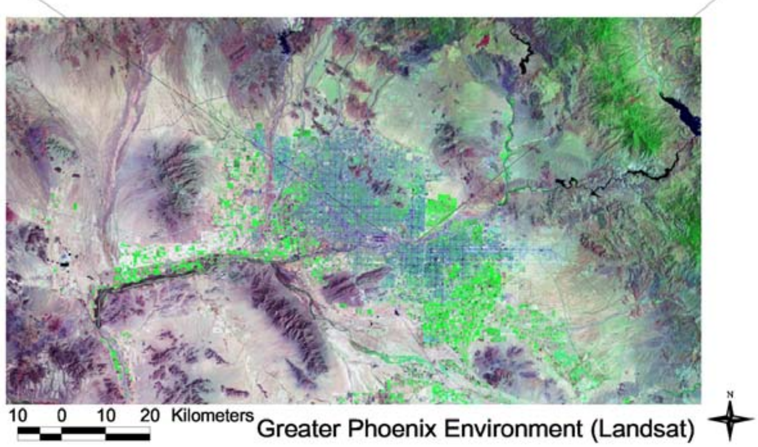


ASU Main with buildings of GIS/Remote Sensing scientists in yellow



Greater Phoenix Environment (Landsat)

(1) Problem definition: Geographic information systems, remote sensing, and related technologies (GIS/RS)[1] have been used as tools for spatial data handling and analysis for nearly forty years. These technologies continue to help scientists determine what is at a particular location, describe spatial patterns and interactions, establish how these patterns came about, and develop models to simulate spatial processes. One of the greatest opportunities for capitalizing on 21st century technological trends is to improve the theory and tools of the scientist to organize and analyze information that is fundamentally indexed spatially, temporally, and probabilistically. Such tools can be applied to complex research efforts on environmental and human interactions, digital government and homeland security, futures analysis and modeling, spatially-based decision support (SDSS) and planning, and transportation and land-use planning.

Investment by Arizona State University has the potential to advance GIS/RS theory and technology. We propose to establish a **Geospatial Science Center (GSC)**. Its mission is to enable and catalyze interdisciplinary research efforts that advance our understanding of geographic processes and spatial relationships emphasizing urban environmental systems through improved theory, methods, technology, data, and community outreach.

The Center will be focused initially on geospatial analysis of urban environments worldwide. It builds on ASU's existing strength in urban environments, dovetails significantly with other ASU areas of emphasis, and provides ample opportunities for synergism (Figs. 1 and 2). Currently, scattered research groups pursue basic research in the science and application of GIS/RS largely independently (see cover image). Better coordination among them enhances capabilities for all and expands the use of these tools within the ASU and greater Phoenix communities.

A successful center has a specific focus and specific sources of core funding. That funding may be partly internal, but the trajectory of growth is with large external grants and broadens with numerous medium and small grants. CES is a stimulating ASU example with its CAPLTER, SCERP, and IGERT grants and numerous collaborations. Penn State's Earth System Science Center (ESSC) is a relevant example of a science-oriented interdisciplinary center in which earth, atmospheric, and GIS disciplines play leading roles. ESSC is supported by a large and continuing NASA EOS grant among a number of others. Using ESSC as a model, we envision building the GSC on ASU's existing strength in urban environmental systems. To reach national prominence and attract greater funding, the center contributes:

- the **message** of University commitment to funding agencies and our colleagues;
- a **critical mass of resources** (equipment, staff, expertise) needed for larger projects;
- its **presence** on and off campus for attracting students and faculty;
- the **incubation** of ideas to enhance success of cutting edge projects and support younger faculty;
- **inspiration** and **support** of students intellectually and financially;
- **response to the needs of the community** with training, education, and outreach.

This is an ideal time to invest in a center devoted to GIS/RS research. The early leaders in GIS research focused NSF funding on three centers: UC - Santa Barbara, U. Maine - Orono, and SUNY Buffalo. However, NSF has scaled back its strategy of concentrated investment in these particular centers, partially because their ambitious research agendas were unfocused and administratively over-centralized. Other groups established research programs focused heavily on standard applications and education/curriculum. ASU is special with its collaborative interdisciplinary contributions to GIS/RS. The wealth of ASU research on the urban environment provides a fertile source of problems for theoretical and applied GIS/RS research. The improved theory in turn yields greater efficiency and discovery in urban environmental investigations. This cycle of theory, application, and its dissemination via education and training will propel ASU through this window of opportunity to become a national leader.

[1] The acronym "GIS/RS" will used throughout the proposal in reference to geographic information system, remote sensing, spatial decision support systems, global positioning systems, and other geospatial technologies.

(2) ASU's current standing: We envision a Center that supports GIS/RS research in four primary areas: scientific applications, theory and tool development, data, and education (Fig 1).

Scientific Applications: Studying the interaction between human activities and natural processes in the urban environment requires many GIS/RS capabilities such as synthesis of disparate datasets, statistical tools, modeling approaches, and appropriate visualizations.

ASU strengths: Researchers in numerous disciplines utilize GIS/RS tools. Examples include remotely sensed land use data integrated into atmospheric models (Zehnder); urban environment monitoring with the Advanced Spaceborne Thermal Emission and Reflection Radiometer, or ASTER (Stefanov, Christensen, Redman); human and plant interaction dynamics (Briggs, Klopatek); urban carbon dioxide dynamics (Balling, Wentz, Gober, Klopatek, Day); urban and transportation modeling (Burns, Kuby, Maltz, Guhathakurta); spatial decision support systems (Kuby); dynamics of cultural landscapes in urban and rural watersheds from alternative environmental policies and plans (Musacchio); earth science data systems, urban geomorphology, visualization (Arrowsmith, Stefanov, Reynolds, Fouch); and Morrison Institute's urban analysis.

Possible opportunities: These scattered research groups utilize GIS/RS as investigation tools. A coordinated Center would facilitate research integration, broaden the range of GIS/RS research by providing new scientists with expertise, opportunities, and resources, and ultimately place ASU in a leadership position in the application of GIS/RS research to urban environmental applications yielding increased grant success for future proposals.

GIS/RS Theory and Tools: The scientists indicated in the previous section utilize the capabilities of GIS/RS to describe, explain, simulate, and optimize various spatial and temporal processes. Generalization and refinement of these tools by constructing new data models, developing sensor technologies, improving spatial cognition theory, applying advances in spatial statistics, strengthening decision support tools, bridging semantic gaps with ontological improvements, and visualization are a comparative research-based strength of the proposed Center.

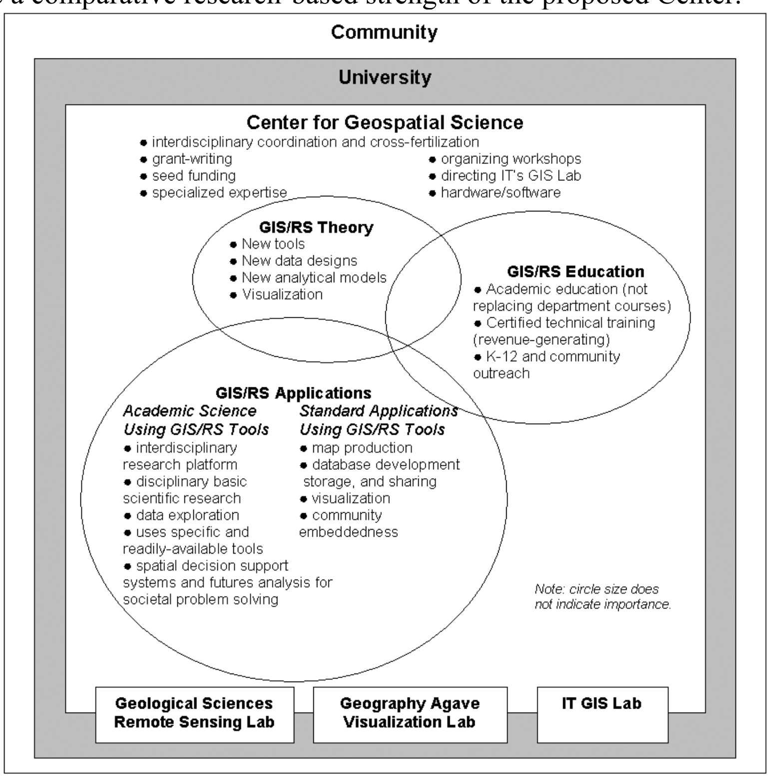


Figure 1. The GSC combines theory, applications, and education in GIS/RS and coordinates with several existing campus facilities. It provides interdisciplinary coordination and cross-fertilization among diverse groups developing, applying, and educating with GIS/RS to build capacity and thus improve extramural funding.

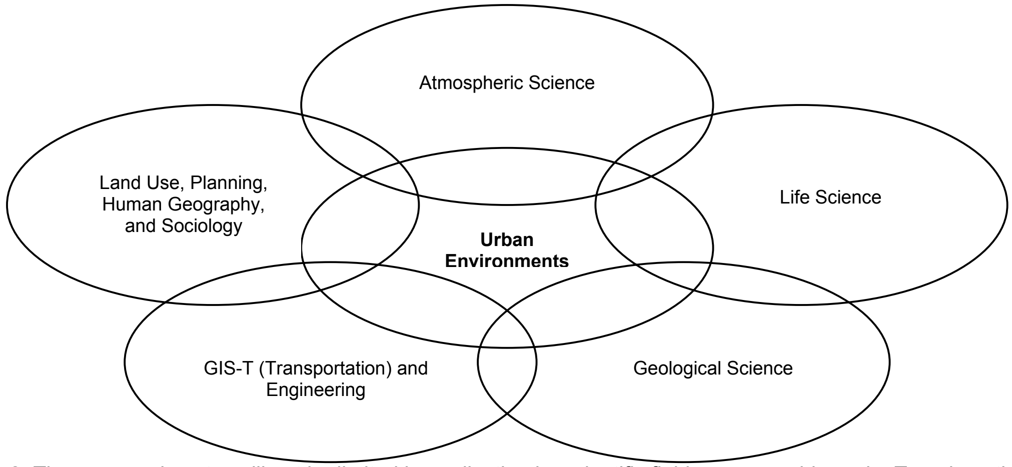


Figure 2. The proposed center will not be limited in application by scientific field or geographic scale. To gain national prominence, it will help to build on ASU's strength in urban environments. As Figure 2 indicates, the proposed center would focus on GIS/RS in ASU's existing areas of strength that overlap with urban environments. Think of the center as serving the union of these areas, not just their intersection, at scales from local to planetary.

Existing strengths: ASU researchers interested in GIS theory development include the areas of spatial analysis (Wentz), SDSS (Kuby, Maltz, Cochran, Guhathakurta, Kirkwood), and visualization (Edsall). ASU is a member of and sponsors meetings of the University Consortium for GIS (UCGIS), whose mandate is to foster theoretical GIS/RS research. The ASU Planetary Exploration Laboratory (Christensen) is a leader in imaging system development for planetary remote sensing, emphasizing the discriminating power of thermal infrared spectra for rock properties and mineralogical mapping. The allied Geological Remote Sensing Laboratory builds on this expertise to focus on remote sensing of terrestrial materials (geological, biological, and built) and surficial processes using a wide range of airborne and satellite-based sensors, field investigations, and analysis tools (Stefanov).

Potential opportunities: To attain national recognition, ASU should hire a high profile scientist with interest in GIScience theory and with a track record of obtaining extramural funding (see investment strategies below). We can capitalize on the established leadership in remote sensing to pursue larger projects in terrestrial sensor development and quantitative remote sensing development and applications. The existing remote sensing research capabilities of ASU could be improved by hiring a scientist with interests in active sensor (radar or lidar) data analysis.

Data acquisition: Inherent to research support is the acquisition and dissemination of geospatial data. Geospatial data representing the human and natural environment are highly heterogeneous in format, quality, size, and reference frame. A goal of the Center will be to provide straightforward access to multi-purpose data sets in support of the research described above.

Existing strengths: The Information Technology (IT) GIS laboratory (Hutchins, Director) and the CES Informatics Lab (McCartney) perform many of these activities in support of CAPLTER, other externally funded research, and Intergovernmental agreements. Also, data acquisition for urban infrastructure management and security (Burns, Hutchins) is growing.

Potential opportunities: The integration of the GIS Lab and its activities into the center is one possibility with the primary target being the development of Internet Mapping Services that provide integrated data via the Internet to a wide audience (Hutchins, Arizona Geographic Information Council President). A remotely sensed data acquisition program is another priority.

Education: In many fields, such as urban planning, GIS/RS are essential tools and knowledge of their application is a minimum requirement. Students and professionals require education and training.

Existing strengths: Interdisciplinary graduate certificate, Geography undergraduate certificate (under review), Geological Sciences remote sensing courses (Christensen), ESRI partnership.

Potential opportunities: Through Continuing Education, the Center can provide training to professionals from a wide variety of careers. Many of these professionals can in turn provide synergistic opportunities through contracts, student internships, and data exchange/access. We could also target a faculty hire in remote sensing for education with possible linkage with the Center on grant proposals.

(3) Potential sources for extramural funding: The agencies and programs described below have a record of supporting GIS/RS research. The Center could be competitive in any of these.

Environmental Protection Agency (EPA)

- Smart Growth program focuses on understanding sprawl and working with municipalities, $50-100K/yr, new proposals evaluated every four months.
- Science to Achieve Results (STAR) program aims to understand human/environment relations on various specific topics (some with an urban focus).
- Research Fellowships program solicits proposal on a wide range of specific topics that vary each year, for example arsenic in drinking water topic closes January 2003.

National Science Foundation (NSF)

- Information Technology Research program deals with all aspects of IT with particular interest in interdisciplinary research; GIS/RS theory being one IT challenge. This program funded part of Penn State's Geovista Center. NSF intends to spend ~ $145M in FY2003.
- Biocomplexity in the Environment program aims to investigate urban and environmental systems using advanced scientific methodology, such as quantitative modeling and visualization. NSF intends to spend ~$36M in FY2003. Geographers have been particularly successful in the Dynamics of Coupled Human and Natural Systems program.
- Digital Government program funds research at the intersection of computer information sciences and government information services, with the goal to bring advanced information technology to the government community. The Center could promote the development of the information technology tools to achieve this goal in the greater Phoenix region.
- IGERT program aims to catalyze an institution's graduate education. ASU has a good reputation at NSF with IGERT, and currently has two programs with others recently proposed. An IGERT in GIS was awarded to SUNY Buffalo. The Center could develop an IGERT in integrated urban environmental analysis and modeling. Invited proposals are due April 2003.
- Decision Risk and Management Sciences supports research aimed at increasing the effectiveness of decision making. Kuby (Geography) was awarded a grant from this program based on transportation and SDSS.
- The Geography and Regional Science Program (GRS) supports basic research on problems related to human, physical, and biotic systems. This program supports theory-based GIS research. Awards range from $90K to $300K/year. Next closing date is Feb 2003.
- The Division of Undergraduate Education supports innovation in teaching. Gober and Kuby received a grant for workshops on GIS-based interactive human geography teaching materials.

NASA

- Office of Biological and Physical Research offers opportunities for both applied and theoretical GIS/RS research. Closing dates for grants are Nov and Dec 2002.
- Office of Earth Science offers excellent opportunities for applied RS research for modeling and predicting various aspects of the earth's environment.
- The GLOBE program offers opportunities to improve K-12 student achievement in mathematics and science. ASU's CRESMET is bringing GIS/RS tools into the K-12 classroom.

World Bank

- The Information for Development Program supports research aimed at information technologies for e-Government. The Center's aim would be to involve local government in data acquisition and analysis.
- Global Environment Facility provides grants to achieve environmental benefits in the areas of climate change, biodiversity, international waters and ozone-layer depletion.

Private Investment

- In-Q-Tel invests in cutting edge IT technology for defense applications. Of their five broad commercial technology areas, Geospatial Technology, Knowledge Management and Visualization, Distributed Data Collection are potential targets for partnerships with the Center.

(4) Suggestions for ways to invest: We envision a Center that is comprised of an executive committee; a Director (interim until filled with targeted hire) who has the responsibility of coordinating research efforts, writing grant proposals, and managing the Center; academic professionals and graduate research associates to execute research; and support staff. Profiles of a potential targeted hire:

Michael Goodchild, UCSB, NCGIA director, National Academy of Sciences Member
Donna Peuquet, Penn State, GeoVista Center, Apoloa Project, director
Harvey Miller, University of Utah, Editor of International Journal of GIScience
David Mark, SUNY - Buffalo, NCGIA director, IGERT in GIScience director
Max Egenhofer, University of Maine, NCGIA director
Daniel Brown, University of Michigan, director Environmental Spatial Analysis lab
Richard Aspinall, University of Montana, NSF director SBS, director Montana GIA lab
Scott Goetz, U. of Maryland, Mid-Atlantic Regional Earth Science Applications Center
Dawn Wright, Oregon State University, Marine GIS and Remote Sensing
John Landis, UCB, urban GIS/RS applications

Renovated facilities: Technical activities of the Center could be combined with the IT GIS lab. The lab is being reconfigured with high-speed connections, new layout, and video-teleconference capability. Newly vacated space on the second floor of SCOB could be allocated for a dedicated teaching laboratory, seminar room, and administrative activities.

Staff: Support staff would consist of a certified ESRI instructor, administrative assistant, computer system administrator, and a remote sensing technical expert.

Graduate student stipends: We intend to imitate the Urban Ecology IGERT for graduate support by fully supporting a few students and offering travel and research equipment to others.

Travel: Support for visiting scholars and travel to possible funding agencies.

Table 1. Internal seed fund budget

Yearly investment level	**$100K/year**	**$350K/year**	**$750K/year**
A. Salary and Wages			
1. Director	6,000	30,000	30,000
2. Academic Professional	0	50,000	50,000
3. Postdoctoral Researcher	0	0	23,333
4. Technical staff - system administration/web development/programmer	0	45,000	100,000
5. ESRI-certified instructor	15,000	15,000	15,000
6. Administrative staff	0	15,000	30,000
6. Graduate students	20,000	26,667	100,000
8. Undergraduate students	1,333	2,000	5,000
B. Fringe Benefits			
1. Senior Personnel	6,300	46,500	74,500
2. Graduate	2,000	2,667	10,000
3. Undergraduate	133	200	500
C. Equipment	10,000	20,000	50,000
D. Travel	500	2,000	10,000
E. Seed Grant Support	36,667	83,333	200,000
F. Other Direct Costs			
1. Materials and Supplies	833	1,000	5,000
2. Graduate student incentive	1,000	5,000	10,000
Average total cost per year	**$99,767**	**$344,367**	**$713,333**

Seed grants: We plan to emulate the CLAS multi-disciplinary research incentive program. Our program would solicit proposals from ASU scientists from different disciplines and offer support (e.g., access to laboratory facilities, technical advice, summer salary, RA, data, equipment). In return, scientists would be expected to submit an external grant proposal.

Funding at an average $100K/yr involves a targeted hire (funds for salary to be negotiated outside of this budget) with these funds to support course release time, a certified instructor for a training course, a graduate associate to assist with grant writing and research, equipment for the teaching facility, money for seed grants, travel resources, and materials and supplies.

Funding at an average $350K/yr would increase the allocation of funds to all activities described previously. Additional funds would be allocated to academic professional and support staff.

Funding at an average of $750K/yr would increase the allocation of funds to all activities described previously. Additional funds would be allocated to a postdoctoral researcher. Rationale for the high allocation of seed money is to encourage grant proposals and interdisciplinary research.

(5) How the center might bring in greater amounts of external support: An integrated GIS/RS center could bring in support associated with three different sources: Center grant proposals, GIS/RS support, and GIS/RS training. A detailed analysis of GIS/RS related funding on campus should be performed each year to monitor return on investment as part of the Center Director's responsibilities.

Center grant proposals: The Director, academic professionals, and postdoctoral researchers associated with the Center would be charged with writing large-sum grant proposals to the agencies and programs described in Section (3). The center would receive 100% of the research allocation and direct costs. Conservatively, these opportunities could generate 1.5M per year (example of a high profile single investigator). Ideally and ultimately, grants could return as much as an average of $4M per year (example of Goodchild's grant record).

GIS/RS Support: Any PI affiliated with the Center who received consulting or research support will be requested to inform the Center that a proposal was submitted and successfully funded. A minimum of 10% of allocation of recognition and incentives will come to the Center. ASU Main funding levels from 2001 indicate $769K to $3223K came to ASU for 16 projects with at least some GIS and remote sensing component. The larger number includes the 2001 CAP—LTER and IGERT Urban Ecology funds.

GIS/RS Training: ESRI-certified two-day training courses could generate $80K/yr in direct income for Center operations and reinvestment.

Analysis of grant income potential: The table below shows an analysis of funding and investment levels. Conservatively assuming that new GIS/RS funding would be similar to 2001 levels ($769K to $3223K), the five year total extramural funding increase would be $3.7M to $16M. 10 to 1 return with three years investment would thus be $124K--$533K/year. A more optimistic analysis includes Center grants, with a total potential yield of $11.2--$36M. 10 to 1 return with three years investment would be $374K--$1.2M/year. All of the scenarios but the most optimistic require investment levels within the range specified by the VPREA.

Table 2. Analysis of return on investment

	Yearly grant *income*		5 year total		Yearly *investment* with 10-1 ROI for 3 years	
Scenario	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Conservative	$746,503	$3,200,799	$3,732,515	$16,003,995	$124,417	$533,467
Center grants	$1,500,000	$4,000,000	$7,500,000	$20,000,000	$250,000	$666,667
Total	$2,246,503	$7,200,799	$11,232,515	$36,003,995	$374,417	$1,200,133