



COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 01-2 NSF 00-126	FOR NSF USE ONLY
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NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE Arizona State University	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE Arizona State University Tempe, AZ. 85287
AWARDEE ORGANIZATION CODE (IF KNOWN) 0010819000	

NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE	ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE
PERFORMING ORGANIZATION CODE (IF KNOWN)	

IS AWARDEE ORGANIZATION (Check All That Apply)
(See GPG II.C For Definitions) FOR-PROFIT ORGANIZATION SMALL BUSINESS MINORITY BUSINESS WOMAN-OWNED BUSINESS

TITLE OF PROPOSED PROJECT **ITR/IM: Tracking the untrackable: Using information technology to chronicle the skyrocketing urban growth of Greater Phoenix, Arizona from 1900 to 2100**

REQUESTED AMOUNT \$ 4,583,798	PROPOSED DURATION (1-60 MONTHS) 60 months	REQUESTED STARTING DATE 07/01/01	SHOW RELATED PREPROPOSAL NO., IF APPLICABLE
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CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

<input type="checkbox"/> BEGINNING INVESTIGATOR (GPG I.A)	<input type="checkbox"/> VERTEBRATE ANIMALS (GPG II.C.11) IACUC App. Date _____
<input type="checkbox"/> DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C)	<input type="checkbox"/> HUMAN SUBJECTS (GPG II.C.11) Exemption Subsection _____ or IRB App. Date _____
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<input type="checkbox"/> NATIONAL ENVIRONMENTAL POLICY ACT (GPG II.C.9)	<input type="checkbox"/> HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.E.1)
<input type="checkbox"/> HISTORIC PLACES (GPG II.C.9)	
<input type="checkbox"/> SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.C.11)	

PI/PD DEPARTMENT Department of Geological Sciences	PI/PD POSTAL ADDRESS Tempe, AZ 852871404 United States
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CERTIFICATION PAGE

Certification for Principal Investigators and Co-Principal Investigators:

I certify to the best of my knowledge that:

- (1) the statements herein (excluding scientific hypotheses and scientific opinions) are true and complete, and
- (2) the text and graphics herein as well as any accompanying publications or other documents, unless otherwise indicated, are the original work of the signatories or individuals working under their supervision. I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if an award is made as a result of this proposal.

I understand that the willful provision of false information or concealing a material fact in this proposal or any other communication submitted to NSF is a criminal offense (U.S.Code, Title 18, Section 1001).

Name (Typed)	Signature	Social Security No.*	Date
PI/PD Ramon Arrowsmith		*ON FASTLANE SUBMISSIONS* SSNs are confidential and are not displayed	
Co-PI/PD Jeremy Rowe			
Co-PI/PD Frederick Steiner			
Co-PI/PD			
Co-PI/PD			
Co-PI/PD			

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in Grant Proposal Guide (GPG), NSF 01-2. Willful provision of false information in this application and its supporting documents or in reports required under an ensuring award is a criminal offense (U. S. Code, Title 18, Section 1001).

In addition, if the applicant institution employs more than fifty persons, the authorized official of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of Grant Policy Manual Section 510; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflict which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Debarment Certification (If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency?

Yes

No

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding \$100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding \$150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

- (1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
- (2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.
- (3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than \$10,000 and not more than \$100,000 for each such failure.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME/TITLE (TYPED) Gary Delago/Interim Director,ORCA		11/27/00
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*SUBMISSION OF SOCIAL SECURITY NUMBERS IS VOLUNTARY AND WILL NOT AFFECT THE ORGANIZATION'S ELIGIBILITY FOR AN AWARD. HOWEVER, THEY ARE AN INTEGRAL PART OF THE INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.

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B Table of Contents (NSF Form 1359)	1 _____	_____
C Project Description (plus Results from Prior NSF Support) (not to exceed 15 pages) (Exceed only if allowed by a specific program announcement/solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)	5 _____	_____
D References Cited	_____	_____
E Biographical Sketches (Not to exceed 2 pages each)	6 _____	_____
F Budget (NSF Form 1030, plus up to 3 pages of budget justification)	4 _____	_____
G Current and Pending Support (NSF Form 1239)	0 _____	_____
H Facilities, Equipment and Other Resources (NSF Form 1363)	0 _____	_____
I Special Information/Supplementary Documentation	1 _____	_____
J Appendix (List below.) (Include only if allowed by a specific program announcement/ solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)	_____	_____
Appendix Items:		

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Project Description

Embracing the complexity of rapid urbanization

Although the American identity is strongly linked to its agrarian past, the present and future are increasingly dominated by urbanization and suburbanization. In the arid and semi-arid portions of the West, this process occurs at dizzying speed. Rural, agricultural, and natural landscapes are converted to suburban and urban use at unprecedented rates. Nowhere is this transformation taking place more dramatically than in greater Phoenix, Arizona. The rate of development is over an acre per hour. More people are moving to Phoenix than to any other Sun Belt city. However, they are also leaving the area in droves. In a recent survey, 2 in 3 Phoenix residents said they would seriously consider moving elsewhere. This phenomenon has come to dominate the political agenda. Yet the complexity of the associated issues has precluded rational dialog and policy suggestions.

The demographic cauldron of Phoenix provides a unique opportunity to chronicle how rapid urbanization impacts the economy, ecology, and social fabric of a modern metropolitan area. But how can one characterize such a complex system in a meaningful way? What sorts of data can be used to document the roots of the current explosion, the path it is taking, and the likely outcomes? How can the lessons uncovered by scientists and engineers be translated into forms that can help political leaders craft public policy? And finally, what role can information technology play in unraveling this seemingly chaotic jumble of forces? These are the questions that we seek to answer.

Greater Phoenix is an ideal laboratory in which to address this challenge, and Arizona State University (ASU) is uniquely positioned to carry it out. ASU has made urban environmental research the centerpiece of its strategic agenda, both for the richness and diversity of the scientific questions it contains, and for the opportunity it provides the University to serve its community. Ongoing projects addressing these issues include one of only two NSF-funded urban Long-Term Ecological Research (LTER) grants (a team effort with 47 co-investigators from 14 ASU departments); an Interdisciplinary Graduate Education and Training (IGERT) program in urban ecology; major NSF grants to study the “urban CO₂ dome” and processes of urban fluid dynamics; a NASA study that monitors growth of 100 desert cities using remote sensing; and close partnerships with a multitude of state and local agencies.

Despite this strong foundation, each component produces a torrent of non-communicating, dynamic datasets that race by too quickly to be effectively integrated or even comprehended. We propose to work with these entities to create a series of multi-dimensional, IT-based tools that help the people of Metro Phoenix grasp the complex steps that created the present configuration, and allow them to intelligently evaluate possible future options. These products, which will combine the latest advances in simulation, information management, and visualization, should be readily transferable to urban centers where unbridled growth is the paramount public concern.

Information management: Creating an urban eAtlas

An electronic and ecological atlas of the greater Phoenix area is an important tool to help answer such questions. It will contain constantly updated representations of biophysical features, the built environment, and demographics. Data will be organized from the past into the future with forecasts of possible changes in 2005, 2010, 2050, 2100. This will be accomplished by applying an XML (Xtended Markup Language) implementation to facilitate machine parsing of metadata qualifying data and modeled scenarios to transparently locate, access and ingest any given dataset or modeled scenario on demand. These data and models are very diverse. 2-D bit maps (i.e., the satellite imagery) combined with climate/weather data (large 3-D grids) along with text data (demographic data), and vector data (land use coverages) are simulated via models that may require pixel/voxel

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<-> vector conversion. Unlike traditional atlases, the data in the urban eAtlas will not rest on our servers, but will evolve through our virtual and operational relationships with data providers and models. We will access (and possibly update) their data and model scenarios “on the fly” as part of a user’s interaction.

The urban eAtlas will provide access to raw data, as well as web-based tabular, graphical, and virtual modeled representations. A website will provide easy access to both interactive maps, and also N-Dimensional representations (in which 3 dimensions come from the spatial aspects of the view, a fourth dimension from time, and the parameters denoted by variations in representation color or texture). Information technology tools will support the analysis and synthesis of information, data fusion, data mining, visualization, simulation, and web-based multilevel user (student/decision maker/scientist) inquiry.

We can access, and hopefully begin to understand, the diverse data streams that give us a representation of what is happening. For example, traffic data are gathered in real time by the Arizona Freeway Management system, air quality data are reported by Arizona Department of Environmental Quality, and precipitation and runoff data are collected by the Maricopa County Flood Control district. These data have high spatial and temporal resolutions and provide excellent calibrations for model results and tests of diverse connections among natural and urban processes.

Urban environmental scenarios explored with multiscale coupled models and high quality data

The power of the urban eAtlas goes beyond dynamic depiction of the rich natural and urban landscape. We will apply multiscale, coupled, deterministic and empirical models to the complex urban-desert system to make useful predictions of relevant parameters, such as: air and water quality, real estate values, and wildlife habitat. By considering century-long timescales, we justify the inclusion of geologic factors in our scenarios. For example, we expect to apply some common or optimal land use change models, but what would happen to land use if there were a 20-year drought? What are the long-term land-use consequences of various growth-related ballot propositions? A major concern of the metropolitan Phoenix area and other regions is non-attainment of EPA urban air quality standards. We can both monitor air quality and explore a multitude of mitigation options. ASU scientists have considerable experience in modeling urban air sheds and mesoscale climate. What would be the socioeconomic consequences in Phoenix if a major earthquake hit the Los Angeles region? Once we have our inventory of materials and processes operating in the area, we can produce a detailed characterization of such effects with the urban eAtlas. It would have far reaching implications for much of the U.S. and abroad, and lessons from that portrayal could be easily transferred to other major urban centers.

How do environmental hazards, changing land uses, urban growth, and economic transformations change the 'riscscape' of the city? For example, we can model and measure how changing urban land uses and transportation networks shift ambient pollution in the region over time. We can also identify baseline indicators of sustainability. They would be both environmental (e.g., water quality and quantity) and demographic (e.g., population migration). Sensitive indicators can be transferred to other urban systems.

Information Technology and Information Management tools and research

Our major efforts will be to establish standards, query structure, metadata for both data and models, and the virtual and operational relationships among the data producers, modelers, and users. Much of what has preceded is general commentary about the vision of the urban eAtlas. These efforts will produce a prototype. We will set up the standards and tools to create a scalable model that can grow and adapt over time. It will develop in the heterogeneous environment of the University and

will include partnerships with agencies generating and maintaining applicable data. As a pilot portion of this project, we will focus on a representative group of the major datasets and models: topography, land cover, land use, real time traffic and air shed/watershed monitoring, quality of life measures such as median family income, mesoscale climate modeling, and remote sensing. We will identify and coordinate datasets and modeling tools – some from state agencies, others from across disciplines that address environmental data that interact to affect air quality, for example. The goal is to provide a powerful tool for analysis, and build partnerships to demonstrate the practical value of science in the political process. The sections below describe the major tasks.

Coordination of diverse data/model content, types, formats and procedures

We wish to improve the interaction between scientists and decision makers by providing simplified access to modeling and visualization tools to help them analyze complex relationships among data and envision different scenarios. A key initiative of the Governor of Arizona and state technology planners is to create a single entry point for electronic access to state data and services. We will build on the current role and reputation of ASU and its Visualization, GIS, and environmental planning support for state agencies. We will leverage the powerful interdisciplinary research teams and environment that have emerged at ASU in recent years to develop the necessary standards and cooperative agreements to prove concepts and lay the groundwork for expansion. By focusing on the standards and coordination rather than a fixed central database, we will more effectively leverage NSF project funding to create partnerships between scientists at ASU and state agencies and educators that will have significant impact far beyond the original project.

Creation of an integrated structure to define and acquire data in response to queries

We will use these agency and university sources to identify the varied data sets and modeling tools involved, produce a data description and organization schema and XML structure for access, develop programming to overlay displays, and provide interactive linkages among key visualization and modeling applications. The project team will work with emerging GML (geographical markup language) data definitions to describe content features and elements, and develop style sheets for display incorporating elements from multiple data sources. Web mapping specifications (WMS) will support merging data from multiple sources in a relatively small .gif. or .jpg file format that supports web based display. Open locator services (OpenLS) will also be explored to dynamically link and display data from location-aware applications and devices.

Creation of a query interface to search, display, interact with, and analyze databases and models.

Creation of a simple web accessible user interface, the capacity to post analytic and interpretive data for other users, and the ability to access and re-evaluate the original data will create a valuable, accessible, interactive resource. This functionality has the potential to dramatically increase the range of users and potential impact on education training and decision-making. A model using this approach has been developed for anthropologic pottery data and is incorporating datasets and models from other disciplines (Rowe and McCartney are CoPIs; KDI: 3D Knowledge: Acquisition Representation & Analysis in a Distributed Environment; <http://3dk.asu.edu>).

Guidelines for data acquisition, database population, file formats, & metadata over time

Standards and descriptive schema will be developed as a bridge for access to multiple databases. Standards for data description, file formats, and cataloging will simplify coordination among agency and research participants. We will create a framework for monitoring both the interaction of people and the environment, and of access to the data across disciplines and to planners and decision makers. Given the rapid changes in the region, we will document change during the life of

the initial project. Our goal is to create a process that will continue beyond the life of the grant to provide access to data and evaluate changes and quality of decision making over time.

Educational Components

A significant initial effort to establish common vocabulary, descriptions, and intellectual strategies will enable smoothly functioning cross-disciplinary project teams. A second phase will address interaction between the project team and city-county-state-federal entities. Once the tools and interface have been developed, outreach activities will involve training and expanded use by state agencies in addition to traditional academic outreach through conference presentations and publications. We will also join with established outreach efforts (Arizona Geographic Alliance and Ecology Explorers; see below). The web-accessible modeling and visualization tools will support access by high school, community college, and university science and government users. Beginning in year 2, we will introduce an interested group of high school, community college, and university faculty to environmental modeling and visualization for their curriculum.

Arizona Geographic Alliance. The urban eAtlas articulates with several K-12 educational standards in the state of Arizona, most notably those in Geography (see <http://alliance.la.asu.edu/azga/>; a network of more than 2700 teachers). The urban eAtlas will facilitate K-12 students learning about urban growth issues while they participate in the research process. Teacher training through a series of weekend workshops will enhance the ability of instructors to convey how the scientific method works.

Ecology Explorers. This program (<http://caplter.asu.edu/explorers/>) gives Phoenix area K-12 students and teachers opportunities to do scientific research with the CAP LTER project. Students use the data they have collected to look for patterns in their own research sites (schoolyard or backyard), and the data can be shared with other researchers and school children to see what patterns in nature exist across the entire Phoenix area. The urban eAtlas project facilitates cross-area comparisons experiments that combine other data and model results.

Evaluation and Assessment

This project provides a valuable opportunity to evaluate and assess the interaction between researchers and business, government, educational, and public users. Formative evaluation will guide the development of collaborative models, standards, and project design decisions. Interfaces and tools for multi-disciplinary data analysis will be evaluated in terms of effectiveness within the project design team. Training and educational components for external users will be evaluated and revised during the course of the project. Summative evaluation will be used to determine progress of the completion of key project elements.

Acting in an advisory and review mode, prominent public officials, scientists, and interested citizens will work with the management team in the form of a *Multi dimensional planning advisory council*. The council will provide focus, database evaluation, scenario generation, and project promotion to the greater Phoenix community and beyond. Potential members include many of the most prominent community and business leaders in the region. Additional guidance will come from regular consultation with engineers and principals of Environmental Systems Research Institute, Inc, (ESRI)—the producers of the industry standard GIS—ArcInfo.

Collaboration with the Urban Security Team at Los Alamos National Laboratory

Integrated modeling and analysis of urban systems are the expertise of Los Alamos National Laboratory (LANL) Urban Security Team colleagues. This group has been successful at simulating realistic urban security scenarios such as an Airborne Toxic Release/Emergency Response

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(<http://www.lanl.gov/orgs/tsa/tsa4/aquality/urban.html>). Our LANL collaborators will focus their efforts on modeling and scenario generation. The integrative training aspect of this project will be collaborative and sustained interaction via graduate student and post doc work with the LANL team. They have had much success with students spending extended periods at LANL in the rich, creative, and technical environment where coding, algorithms, and scenarios can be developed and tested, and then brought back to ASU and implemented in the urban eAtlas, as well as applied to the urban security research problems at LANL.

Management plan and budget

The PIs will collectively manage the project with input from ASU colleagues, related state agencies, and LANL. Interdisciplinary teams of faculty, postdoctoral scholars, and graduate students will bring knowledge from their disciplines to discover, compile, validate, and work with data, and develop and apply the visualization and modeling tools needed to understand them.

The project staff will include an Information Technology specialist to manage the technical coordination of the project, spend time in the field working with data and model providers, and assist in developing standards and schema for data interchange. A professional Evaluation, Education and Outreach (EE&O) staff member will manage the evaluation and assessment portions of the project, and provide outreach to educators and students, decision makers and citizens, and natural and social scientists. Information design as it relates to interactivity, organization, iconography, hierarchy, communication, and comprehension will be important aspects of this project. How will people use and access this information and how could it be enhanced by an interactive context? To address these issues, the project team will also include a graphic designer to help visually translate data and model results as well as design the web user interfaces to be effective for scientists, and to students, policy makers, and the general public.

This project is strongly supported and was partially initiated by ASU Vice Provost for Research Jonathan Fink. We have an informal commitment for sufficient space (and its renovation), computer support, and the Information Manager position as an ASU cost-share.

Project Schedule

Task	Year 1	Year 2	Year 3	Year 4	Year 5
Develop project teams	█				
Identify project data, modeling and visualization tools	█				
Identify agency data sets and obtain access	█				
Continue development of relationships with state agencies and decision makers		█	█	█	█
Develop data standards, schema, definitions and communication protocols for project team data	█	█	█	█	█
Data conversion and development of tools	█	█	█	█	█
Interface development	█	█	█	█	█
Formative evaluation feedback/revision cycle for data definitions	█	█	█	█	█
Formative evaluation feedback/revision cycle for interface	█	█	█	█	█
State agency and k-20 workshops		█	█	█	█

Summary

The greater Phoenix Arizona region comprises a desert landscape transforming through a suburban matrix to an urban center. We propose to take the pulse of the region and present a prognosis for growth. Our challenges are to virtually integrate diverse datasets, to develop and apply models of the urban-desert system in ways that embrace its inherent complexity, and to make our understanding useful for those who make decisions.

Biographical Sketch: Principal Investigator

J Ramón Arrowsmith

November 26, 2000

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Academic Training

- Whittier College
B.A. (Summa Cum Laude) in Geology and Spanish, 1989, supervised by Dr. Dallas D. Rhodes.
Presidential Scholarship at Whittier College (full tuition 1985–1989).
- Stanford University
Ph.D. Geological and Environmental Sciences, 1995, supervised by Dr. David D. Pollard.
Dissertation title: “Coupled Tectonic Deformation and Geomorphic Degradation along the San Andreas Fault System.”
- Stanford University, Department of Geological and Environmental Sciences
Post-Doctoral Scholar April 1, 1995–July 31, 1995

Appointment

Arizona State University, Department of Geological Sciences
Assistant Professor of Geology
August 1, 1995–Present

Publications closely related to the project

- Crider, J. G., Cooke, M. L., Willemse, E. J. M., and Arrowsmith, J. R., Basic mechanics of jointing and faulting through interactive linear-elastic crack models, in *Microcomputers in Structural Geology*, De Paor, D. (Ed.), Pergamon Press, New York, 359–388, 1996.
- Boschi, E., Giardini, D., Pantosti, D., Valensise, G., Arrowsmith, R., Basham, P., Bürgmann, R., Crone, A., Hull, A., McGuire, R., Schwartz, D., Sieh, K., Ward, S., and Yeats, R., New trends in active faulting studies for seismic hazard assessment, *Annali di Geofisica*, 39, 1,301–1,307, 1996.
- Arrowsmith, J. R., McNally, K., and Davis, J., Potential for earthquake rupture and M 7 earthquakes along the Parkfield, Cholame, and Carrizo segments of the San Andreas Fault, *Seismological Research Letters*, 68, 6, 902–916, 1997.
- Hilley, G. E., Arrowsmith, R., and Pollard, D. D., A geographic information system applied to areas of active tectonics, *GSA Abstracts with Programs*, 28, 7, 265, 1996.
- Hilley, G. E., Arrowsmith, R., and Pollard, D. D., Mechanical modeling and visualization of fault bends using boundary elements methods and geographic information systems, *EOS Transactions AGU*, 1996.

Additional publications

- Hilley, G. E., and Arrowsmith, J. R., Thrust fault slip rates deduced from coupled geomorphic and tectonic models of active faults and folds in the San Francisco Bay Area: Collaborative Research with Arizona State University, and University of California, Davis; USGS award number 1434-H-97-GR-03113, *National Earthquake Hazards Reduction Program Final Technical Report*, 9 plates, 82 pp., 2000.

Arrowsmith, J R., and Strecker, M. R., Seismotectonic range-front segmentation and mountain-belt growth in the Pamir-Alai region, Kyrgyzstan (India-Eurasia collision zone), *Geological Society of America Bulletin*, 111, 11, 1,665–1,683, 1999.

Arrowsmith, J R., Rhodes, D. D., and Pollard, D. D., Morphologic dating of scarps formed by repeated slip events along the San Andreas Fault, Carrizo Plain, California, *Journal of Geophysical Research*, 103, B5, 10,141–10,160, 1998.

Arrowsmith, J R., Pollard, D. D., and Rhodes, D. D., Hillslope development in areas of active tectonics, *Journal of Geophysical Research*, 101, B3, 6,255–6,275, 1996. Correction: *Journal of Geophysical Research*, 104, B1, 805, 1999.

Arrowsmith, J R. and Rhodes, D. D., Original forms and initial modifications of the Galway Lake Road scarp formed along the Emerson Fault during the 28 June 1992 Landers, California, earthquake, *Bulletin of the Seismological Society of America*, 84, 511–527, 1994.

Synergistic activities

- Land–use change and ecological processes in an urban ecosystem of the Sonoran desert (CAP-LTER); National Science Foundation Long–Term Ecological Research project core scientist
- Integrative Graduate Education and Research and Training in Urban Ecology; National Science Foundation project senior faculty
- Arizona State University representative to the Southern California Earthquake Center
- USGS National Earthquake Hazards Reduction Program proposal review panel (1996–1998)
- NSF-AGU Geoinformatics interim steering committee (2000–Present)
- Arizona state government service: ASU representative of Arizona Earthquake Information Network and member of Arizona Council for Earthquake Safety
- Courses taught at Arizona State University: Introduction to Geology, Structural Geology, Geomorphology, Computers in Geology, Desert surface processes and Quaternary geology seminar; Field Geophysics (with James A. Tyburczy), Advanced Field Geology (with Philip A. Pearthree, Arizona Geological Survey), Advanced Structural Geology (with Stephen J. Reynolds).

Collaborators & Other Affiliations

Collaborators in the last 48 months

R. Bürgmann (UC Berkeley), R. Butler (U. Arizona), E. Cowgill (UCLA), J. Davis (California Division of Mines and Geology), T. Dumitru (Stanford), S. Forman (U. Chicago), G. Gehrels (U. Arizona), D. Granger (Purdue), L. Grant (UC Irvine), T. M. Harrison (UCLA), K. McNally (UC Santa Cruz), P. A. Pearthree (Arizona Geological Survey), D. M. Ragan (ASU), D. D. Rhodes (Georgia Southern University), J. Roering (U. Oregon), R. Ryerson (LLNL), M. Strecker (U. Potsdam), W. Taylor (UNLV), J. Tyburczy (ASU), P. Umhoefer (NAU), A. Yin (UCLA)

Graduate Advisor

David D. Pollard, Stanford University

Thesis and dissertation Advisor

Ph.D. advisees: Lee Amoroso, Sarah Robinson, George Hilley, Jeri Young. M.S. advisees: Elizabeth Stone, Stephen Holloway, Heidi D. Stenner, Sean McManus, Keenan Murray, Joshua Roering, Ken Ferguson, Zack Washburn. Visiting student: Laura Colini. Undergraduate thesis advisees: Matthew Baillie, Erin M. Young.

JEREMY ROWE

Head, Media Development
Arizona State University
Tempe, Arizona 85287-0101
(480) 965-8622 (w)
jeremy.rowe@asu.edu

EDUCATION:

EdD. in Educational Policy and Administration, Arizona State University, 1997;
M.A. Educational Technology/Audiovisual Education, Arizona State University, 1977;
B.S. Psychology, Arizona State University, 1974.

ACADEMIC AND RESEARCH EXPERIENCE:

Learning Resources Specialist, Information Technology, Arizona State University – Full 1995,
Associate, 1991; Assistant, 1988.
Faculty Associate, Chandler Gilbert Community College, 1987-88;
Faculty Associate, College of Education, Arizona State University, 1982-85.

PROFESSIONAL EXPERIENCE:

Head, Media Development, Information Technology, Arizona State University, 1988 – 99;
Coordinator of Training Services/ Director of Telecommunications & Media, Chandler - Gilbert
Community College, 1987-88;
Assistant Director, Media Development University Media Systems, Arizona State University,
1982 – 1988.

RELATED PUBLICATIONS:

Fleischhauer, Carl and Jeremy Rowe, American Memory Project, Information Technology It's for
Everyone, proceedings of the Library Information and Technology Association Third National
Conference, edited by Thomas W. Leonhardt, American Library Association, pages 124 - 125.

Rowe, Jeremy, Information Access through Technology - Implications of the Library of Congress
American Memory Project, ConservatioNews, April 1993, Volume 13, Number 1, pages 8-9.

SIGNIFICANT PUBLICATIONS:

Palmquist, Peter, ed. Copyrights and Other Rights in Photographers: A Sourcebook for
Historical Research. Carl Mautz Publishing, Nevada City, California, 2000.

Rowe, Jeremy, An Analysis of Policies Addressing Ownership of Faculty Produced Multimedia
Materials in Higher Education, Doctoral Dissertation, Arizona State University, 1997.

McIsaac, Marina & Jeremy Rowe, National Policy and Intellectual Property Issues, chapter in
New Directions for Community Colleges: Distance Education, University of Oklahoma Press,
May, 1997.

Rowe, Jeremy, Photographers of Territorial Arizona - 1850 - 1920. Carl Mautz Publishing,
Nevada City, California, 1997.

GRADUATE STUDENTS SUPERVISED: 1 M.A. and 1 Ph.D.

RECENT COLLABORATORS:

Razdan, Anshuman, Office of Vice Provost for Research – Director of PRISM, Arizona State University

Collins, Daniel , Fine Arts, Arizona State University

Farin, Gerald, Engineering and Applied Sciences - Computer Science & Engineering, Arizona State University

Henderson, Mark, Engineering and Applied Sciences - Industrial Engineering, Arizona State University

Simon, Arleyn, Anthropology, Arizona State University

McCartney, Peter, Anthropology, Arizona State University

Panchanathan, Sethuraman, Engineering and Applied Sciences - Computer Science, Arizona State University

Ramakrishna, B. L., Center for Solid State Sciences, Arizona State University

GRADUATE AND POSTGRADUATE ADVISORS:

Fenske, Robert, Educational Leadership and Policy Studies, Arizona State University

Hunnicuttt, Kay, Educational Leadership and Policy Studies, Arizona State University

Webb, L. Dean, Educational Leadership and Policy Studies, Arizona State University

FUNDED PROJECTS:

Co-Principal Investigator - Preservation and Access for Electronic Records of Higher Education, \$125,000 National Historical Publications and Records Commission grant funded 11/2000 - 2002

Project team/Scholar – Colorado River: Moving Waters in the Arid West, \$300,000 National Endowment for the Humanities grant funded 2000- 2002

Co-Principal Investigator - KDI: 3D Knowledge: Acquisition, Representation, and Analysis in a Distributed Environment. \$2,100,000 National Science Foundation grant funded 9/1999 to 9/2000. (3dk.asu.edu)

Contract investigator and instructional design consultant - Interactive Nano-Visualization for Science and Engineering Education (IN-VSEE). \$2,250,000 National Science Foundation grant funded 1997-2000. (<http://invsee.asu.edu>)

Consultant and co author of Arizona Humanities Council proposal to U. S. West for Arizona Humanities Council "Cultural Clearinghouse" project to develop WWW presence for the Council and support supplemental grants to provide access to libraries and museums in rural Arizona. \$50,000, 1996

Concept consultant and facilitator for development of Cline Library Pilot Imaging Project to coordinate digitizing historical photographs to provide access to students at distant sites via the Internet, increase electronic access to the collection, and evaluate digital preservation. Initial funding \$80,000 with subsequent expansion. Cline Library, Northern Arizona University, November 1994 - January 1995.

FREDERICK R. STEINER

Director and Professor, School of Planning and Landscape Architecture
Arizona State University, PO Box 872005, Tempe, AZ 85287-2005
Phone: (480) 965-7167; FAX: (480) 965-9656; e-mail: steiner@asu.edu

EDUCATION AND PROFESSIONAL EXPERIENCE

B.S.D., 1972, Design, University of Cincinnati, Cincinnati, OH; Master of Community Planning, 1975, University of Cincinnati, Cincinnati, OH; Master of Regional Planning, 1977, University of Pennsylvania, Philadelphia, PA; M.A., Ph.D., 1986, City and Regional Planning, University of Pennsylvania, Philadelphia, PA; Assistant to Associate Professor, Washington State University, Pullman, WA (1977-1987); Associate Professor to Professor, University of Colorado, Denver, CO (1987-1989); Associate Director of Research to Director, Center for Built Environmental Studies, University of Colorado, Denver, CO (1987-1989); Professor, Arizona State University, School of Planning and Landscape Architecture (1989-present); Chair, Director, School of Planning and Landscape Architecture, (1989-present); Executive Director, Greater Phoenix 2100, ASU Vice Provost for Research (2000-present).

RECENT PROFESSIONAL ACTIVITIES

Rome Prize Fellow, American Academy in Rome (1998); Editorial Board, *Environmental Management*, (1999-present); Editorial board, *Journal of the American Planning Association* (1998-present); Planning Accreditation Board (1998-present), Editorial board and book review editor, *Landscape and Urban Planning*, (1994-present); Editorial board, *Landscape Journal* (1997-present); Board member, International Commission on Agricultural Engineering (1996-present); Board of Directors, Vice President for Research and Education, President Elect, Landscape Architecture Foundation (1994-present); Region 2025 Vision Committee, Maricopa Association of Governments (1997-2000); Board of Trustees, chair of long-range planning committee, member of executive committee, Phoenix Desert Botanical Garden (1993-1999); Task Force on Agriculture and Forestry in Rapidly Growing Regions, U.S. Department of Agriculture (2000).

RESEARCH INTERESTS

Applied landscape ecology, geographic information systems, land suitability analysis, the identification and protection of environmentally sensitive areas, and regional planning.

RELEVANT PUBLICATIONS

Magoni, Marcello and Frederick Steiner. 2001. "The Environment in the Provincial Plan of Cremona, Italy." *Environmental Management* (27, in press).

Steiner, Frederick, 2000. *The Living Landscape* (second edition). New York: McGraw Hill.

Steiner, Frederick, Laurel McSherry, and Jill Cohen, 2000. "Land Suitability Analysis for the Upper Gila River Watershed." *Landscape and Urban Planning* 50(4):199-214.

Steiner, Frederick, John Blair, Laurel McSherry, Subhrajit Guhathakurta, Joaquin Marruffo, and Matthew Holm. 2000. "A Watershed at a Watershed: The Potential for Environmentally Sensitive Area Protection in the Upper San Pedro Drainage Basin (Mexico and U.S.A.)." *Landscape and Urban Planning* 49(3/4):129-148.

Treu, Maria Cristina, Marcello Magoni, Frederick Steiner, and Danilo Palazzo. 2000. "Sustainable

Landscape Planning for Cremona, Italy.” *Landscape and Urban Planning* 47(1/2):79-98.

Steiner, Frederick. 1999. “Environmental and Ecological Planning” in *The Encyclopedia of Environmental Science*, David E. Alexander and Rhodes W. Fairbridge, editors. Dordrecht, The Netherlands: Kluwer, pp. 197-99.

Steiner, Frederick. 1999. “Land Evaluation, Suitability Analysis” in *The Encyclopedia of Environmental Science*, David E. Alexander and Rhodes W. Fairbridge, editors. Dordrecht, the Netherlands: Kluwer, pp. 363-367.

Steiner, Frederick, Laurel McSherry, Dean Brennan, Mark Soden, Joe Yarchin, Douglas Green, James M. McCarthy, Catherine Spellman, John Jennings, and Kristen Barfe. 1999. “Concepts for Alternative Suburban Planning in the North Phoenix Area.” *Journal of the American Planning Association* 65(2):207-222.

Van Lier, H.N., editor, L. Santos Pereira and F. R. Steiner, co-editors. 1999. *CIGR-Handbook of Agricultural Engineering, volume 1. Land and Water Engineering*. St. Joseph, Michigan: American Society of Agricultural Engineers.

Miller, William, Michael Collins, Frederick Steiner, and Edward Cook. 1998. “An Approach for Greenway Suitability Analysis.” *Landscape and Urban Planning* 42(2-4):91-105.

McHarg, Ian L. and Frederick R. Steiner, editors. 1998. *To Heal the Earth: The Selected Writings of Ian McHarg*. Washington D.C.: Island Press.

Steiner, Frederick. 1997. “Environmental Protection” in *Encyclopedia of Rural America: The Land and People*, Gary A. Goreham, editor. Santa Barbara, California: ABC-CL10, pp.232.236.

Thompson, George F. and Frederick R. Steiner, editors. 1997. *Ecological Design and Planning*. New York: John Wiley & Sons. (*Ecological Design and Planning* was translated into Chinese, published by Liu-Ho, Republic of China.)

Whitmore, William, Edward Cook, and Frederick Steiner. 1995. “Public Involvement in Visual Assessment, Verde River Corridor Study.” *Landscape Journal* 14(1):26-45.

CURRENT RESEARCH SUPPORT

27th Avenue Solid Waste Management Facility Master Plan, City of Phoenix, \$26,070 (1998-present); *Integrative Graduate Education and Research Training in Urban Ecology*, National Science Foundation, Senior personnel, \$2,698,494 (2000-present); *Long Term Ecological Project, Land-Use Change and Ecological Processes in the Urban Ecosystem of the Sonoran Desert*, National Science Foundation, Core scientist (part of a 45-member, interdisciplinary faculty team), \$4.2 million (1997-present).

SUMMARY PROPOSAL BUDGET YEAR 1

ORGANIZATION Arizona State University				FOR NSF USE ONLY			
				PROPOSAL NO.	DURATION (months)		
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Ramon Arrowsmith				AWARD NO.	Proposed	Granted	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-mos.		Funds Requested By proposer	Funds granted by NSF (if different)
	CAL	ACAD	SUMR				
1. Ramon Arrowsmith - PI	0.00	0.00	7.00	\$ 42,333			
2. Jeremy Rowe - Co-PI	8.00	0.00	0.00	42,333			
3. Frederick Steiner - Co-PI	5.50	0.00	0.00	42,333			
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0			
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)	13.50	0.00	7.00	126,999			
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (3) POST DOCTORAL ASSOCIATES	12.00	0.00	0.00	956,000			
2. (2) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	199,000			
3. (6) GRADUATE STUDENTS				663,000			
4. (0) UNDERGRADUATE STUDENTS				0			
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0			
6. (0) OTHER				0			
TOTAL SALARIES AND WAGES (A + B)				1,944,999			
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				917,000			
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				2,861,999			
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
Hard Disks and tape drives				\$ 20,000			
Network				10,000			
Peripherals(printers/plotters/digitizer/scanner)				35,000			
Others (See Budget Comments Page...)				78,000			
TOTAL EQUIPMENT				143,000			
E. TRAVEL				10,000			
1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)							
2. FOREIGN				0			
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ _____				0			
2. TRAVEL _____				0			
3. SUBSISTENCE _____				0			
4. OTHER _____				0			
TOTAL NUMBER OF PARTICIPANTS (0)							
TOTAL PARTICIPANT COSTS				0			
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES				30,000			
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0			
3. CONSULTANT SERVICES				0			
4. COMPUTER SERVICES				0			
5. SUBAWARDS				0			
6. OTHER				10,000			
TOTAL OTHER DIRECT COSTS				40,000			
H. TOTAL DIRECT COSTS (A THROUGH G)				3,054,999			
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)							
MTDC (Rate: 52.5000, Base: 2911999)							
TOTAL INDIRECT COSTS (F&A)				1,528,799			
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				4,583,798			
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0			
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				\$ 4,583,798			
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI / PD TYPED NAME & SIGNATURE*			DATE	FOR NSF USE ONLY			
Ramon Arrowsmith				INDIRECT COST RATE VERIFICATION			
ORG. REP. TYPED NAME & SIGNATURE*			DATE	Date Checked	Date Of Rate Sheet	Initials - ORG	

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

**** D- Equipment**

Hard Disks and tape drives (Amount: \$ 20000)

Network (Amount: \$ 10000)

Peripherals\(\printers/plotters/digitizer/scanner\) (Amount: \$ 35000)

Server (Amount: \$ 30000)

Workstations (Amount: \$ 48000)

SUMMARY PROPOSAL BUDGET Cumulative

ORGANIZATION Arizona State University				FOR NSF USE ONLY			
				PROPOSAL NO.	DURATION (months)		
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Ramon Arrowsmith				AWARD NO.	Proposed	Granted	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-mos.		Funds Requested By proposer	Funds granted by NSF (if different)
	CAL	ACAD	SUMR				
1. Ramon Arrowsmith - PI	0.00	0.00	7.00	\$ 42,333			
2. Jeremy Rowe - Co-PI	8.00	0.00	0.00	42,333			
3. Frederick Steiner - Co-PI	5.50	0.00	0.00	42,333			
4.							
5.							
6. () OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0			
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)	13.50	0.00	7.00	126,999			
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (3) POST DOCTORAL ASSOCIATES	12.00	0.00	0.00	956,000			
2. (2) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	199,000			
3. (6) GRADUATE STUDENTS				663,000			
4. (0) UNDERGRADUATE STUDENTS				0			
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0			
6. (0) OTHER				0			
TOTAL SALARIES AND WAGES (A + B)				1,944,999			
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				917,000			
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				2,861,999			
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
			\$ 143,000				
TOTAL EQUIPMENT				143,000			
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				10,000			
2. FOREIGN				0			
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ _____			0				
2. TRAVEL _____			0				
3. SUBSISTENCE _____			0				
4. OTHER _____			0				
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0			
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES				30,000			
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0			
3. CONSULTANT SERVICES				0			
4. COMPUTER SERVICES				0			
5. SUBAWARDS				0			
6. OTHER				10,000			
TOTAL OTHER DIRECT COSTS				40,000			
H. TOTAL DIRECT COSTS (A THROUGH G)				3,054,999			
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)							
TOTAL INDIRECT COSTS (F&A)				1,528,799			
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				4,583,798			
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0			
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				\$ 4,583,798			
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI / PD TYPED NAME & SIGNATURE*			DATE	FOR NSF USE ONLY			
Ramon Arrowsmith				INDIRECT COST RATE VERIFICATION			
ORG. REP. TYPED NAME & SIGNATURE*			DATE	Date Checked	Date Of Rate Sheet	Initials - ORG	

BUDGET JUSTIFICATION

PERSONNEL

Information Manager - \$60k/yr	ASU Cost Share
Evaluation, Education & Outreach Staff	\$133,000
Graphic Design Expert - \$50k/yr @ 25% FTE	\$66,000
Computer System Support - \$50k/yr @ 25%	
Except first year to set up	ASU Cost Share
Professor/PI salaries (3)	\$127,000
Post Docs (3 @ 60k/yr)	\$956,000
Graduate Students (6 @ \$20.8k/yr; AY 50% FTE and Summer 100%)	\$663,000
Fringe @ 25% for staff, 9% for students	\$917,000

Assumes 3% Cost of Living increase per year

OPERATIONS

Local Travel \$2k/yr	\$10,000
Materials/Supplies \$6k/yr	\$30,000
Other expenses \$2k/yr	\$10,000
Hardware:	
Server	\$30,000
Workstations (lab and office)	\$48,000
Peripherals (printers/plotters/digitizer/scanner)	\$35,000
Hard disks/tape drives	\$20,000
Network	\$10,000

ITR/IM: Tracking the untrackable: Using information technology to chronicle the skyrocketing urban growth of Greater Phoenix, Arizona from 1900 to 2100

Personnel

Ramon Arrowsmith, Arizona State University (ASU) Department of Geological Sciences
Frederick Steiner, ASU School of Planning & Landscape Architecture
Jeremy Rowe, ASU Media Development, Information Technology

Robert Bolin, ASU Department of Sociology
John Briggs, ASU Department of Plant Biology
Malcolm Comeaux, ASU Department of Geography
Jonathan Fink, ASU Vice Provost for Research and Department of Geological Sciences
Jana Fry, ASU Information Technology
Glen S. Krutz, ASU Department of Political Science
Peter McCartney, ASU Center for Environmental Studies
Robert Mings, ASU Department of Geography
Melissa Niederhelfman, School of Design
Ron Dorn, ASU Department of Geography
Joseph Zehnder, ASU Department of Geography

The Los Alamos Urban Security team, Grant Heiken and Steven J. Burian (now at University of Arkansas)

Environmental Systems Research Institute, Inc, (ESRI), Jack Dangermond, William Miller, and Susan Crow

Ray Quay, City of Phoenix
Jim Holway, Arizona Department of Water Resources