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Geodesign: Past, Present, and Future



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Introduction

Geodesign is an iterative design method that uses stakeholder input, geospatial modeling, impact simulations, and real-time feedback to facilitate holistic designs and smart decisions.

How did we get here?

What are the current trends in geodesign?

Where might geodesign take us in the future?

The nine articles in this e-book, written by some of the leading thinkers in the emerging field of geodesign, attempt to answer these questions while offering the reader a revealing glimpse into the promise of geodesign: a framework for understanding, analyzing, and acting, with the ultimate goal of creating a better future for us all.

*—Shannon McElvaney, Community Development
Manager and Geodesign Evangelist, Esri*

Beginnings of Geodesign: A Personal Historical Perspective

By Carl Steinitz, Wiley Professor of Landscape Architecture and Planning
Emeritus, Graduate School of Design, Harvard University

Geodesign is a method which tightly couples the creation of proposals for change with impact simulations informed by geographic contexts and systems thinking, and normally supported by digital technology.

—Michael Flaxman and Stephen Ervin, 2010

Geodesign is an invented word, and a very useful term to describe a collaborative activity that is not the exclusive territory of any design profession, geographic science or information technology. Each participant must know and be able to contribute something that the others cannot or do not . . . yet during the process, no one need lose his or her professional, scientific or personal identity.

—Adapted from C. Steinitz, 2012, A Framework for Geodesign, Preface

My first contact with computing occurred in early 1965 at a lunch at the Harvard-Massachusetts Institute of Technology (MIT) Joint Center for Urban Studies, where I was a graduate student fellow. By chance, I was seated next to Howard Fisher, who was visiting



Howard Fisher (1903–1979)

Harvard while considering a move from the Northwestern Technology Institute (now Northwestern University) to the Harvard Graduate School of Design. Fisher, an architect, had invented the Synagraphic Mapping System—SYMAP—in 1963. SYMAP was the first automated computer mapping system that included spatial-analytic capabilities applied to spatially distributed data. It was based on line-printer technology. Its principal technical innovations for graphics were to enable the typeface ball on the printer to be stopped and a series of overprinting commands to be invoked, which then created a gray scale (figure 1). SYMAP had not yet been applied to a substantive problem.

I immediately seized upon the relationship between the capabilities that Fisher described to me and the needs of my doctoral thesis on the perceptual geography of central Boston.

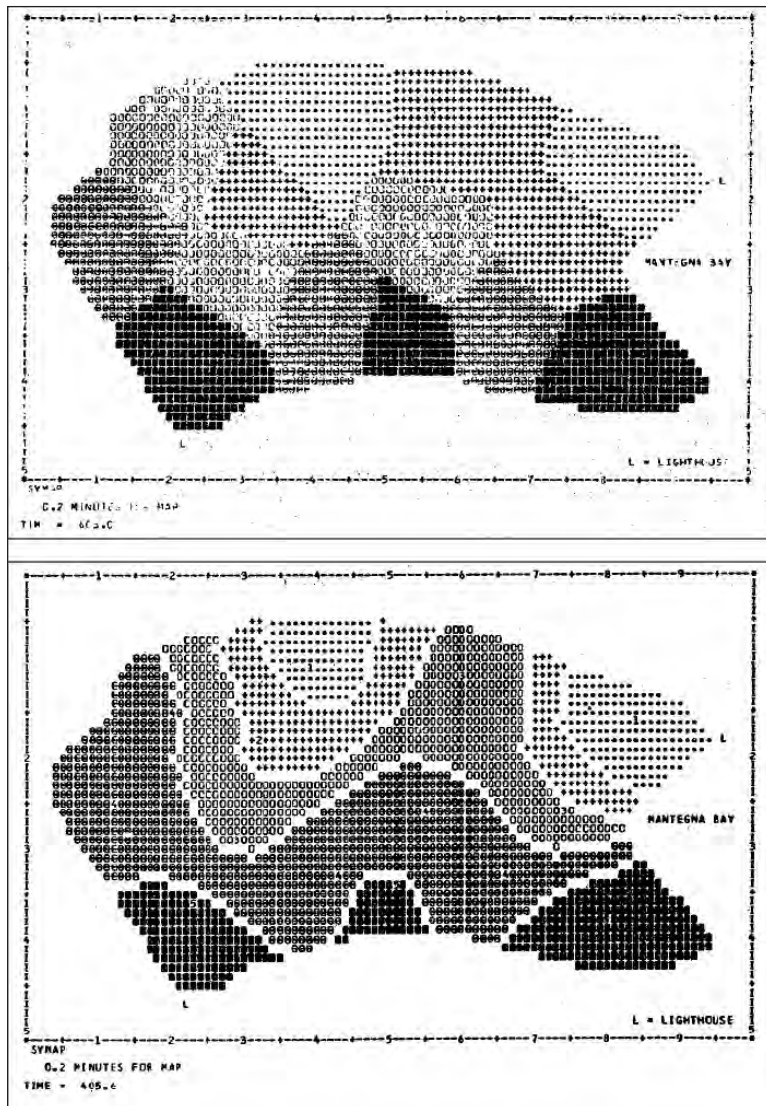


Figure 1. SYMAP Conformant map (top) and Contour map.

With Fisher as my tutor, I gave SYMAP its first applied test. I was trying to explain why some parts of central Boston were included in Kevin Lynch's book *Image of the City* and some were not. I acquired data and mapped and analyzed it (figure 2), including via a graphic spreadsheet-type program, which I had to invent.

Partly because of this work, I obtained my first appointment at the Harvard University Graduate School of Design in 1965 as an assistant research professor and as an initial appointee to the then-new Laboratory for Computer Graphics. The Laboratory for Computer Graphics was established in 1965 with a grant of \$294,000 from the Ford Foundation's Department of Public Affairs and various smaller contributions from and to the Graduate School of Design. Under Fisher's direction, the laboratory assembled a group of bright, energetic, and experiment-minded people, including urban planner Allan Schmidt, water engineer and economist Peter Rogers, and architect Allen Bernholtz.

The laboratory's research was basically of two types. The first was investigation into the analysis and computer-graphic representation of spatially and temporally distributed data and was built largely upon Fisher's SYMAP, which became in its time the world's most widely used computer mapping program. In a very short time, we developed several innovative methods of high-speed electronic digital computer mapping and new techniques for data analysis and graphic display. These made

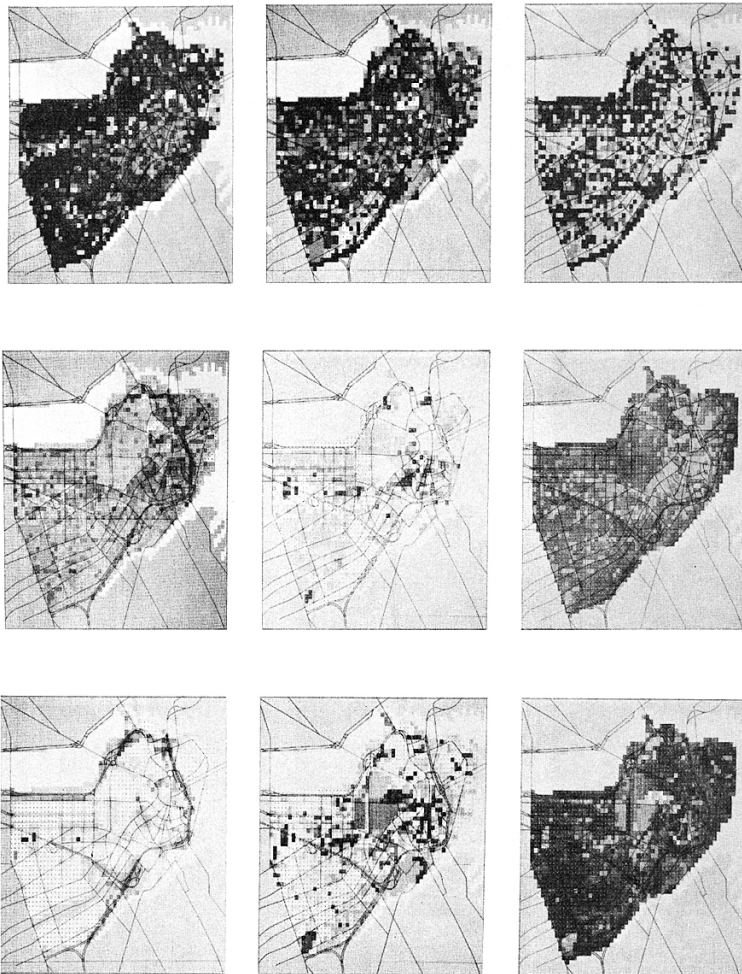


Figure 2. Data and analyses derived from photography and interviews to help explain why some parts of central Boston are memorable.

(Courtesy of C. Steinitz.)

full and efficient use of the accuracy, speed, and cost of the computers of the time.

The second type was research in spatial analysis, mainly related to city and regional planning, landscape architecture, and architecture, with emphasis on the roles of computers in programming, design, evaluation, and simulation. For example, Frank Rens and his team were developing SYMVU, which was programmed to control the view angle and distance of plotted 3D data by enabling rotation of 3D volumes. This was a key step both for animation and for geographically focused global representations.

My assigned role in the lab was to represent landscape architecture and urban and regional planning. However, my personal experience at MIT in thinking about regional change as a designed process with Lynch and Lloyd Rodwin clearly led me to see (and perhaps foresee) computing as providing essential tools and methods for design (figure 3).

My first teaching assignment was in fall 1966 in a multidisciplinary collaborative studio, sponsored by the Conservation Foundation, that focused on future regional development and conservation of the Delmarva Peninsula (Delaware and parts of Maryland and Virginia). In this study, I and a small group of students chose not to use the then-common hand-drawn overlay methods being used by the rest of the class but rather to prepare computer programs in FORTRAN and use SYMAP to make and visualize

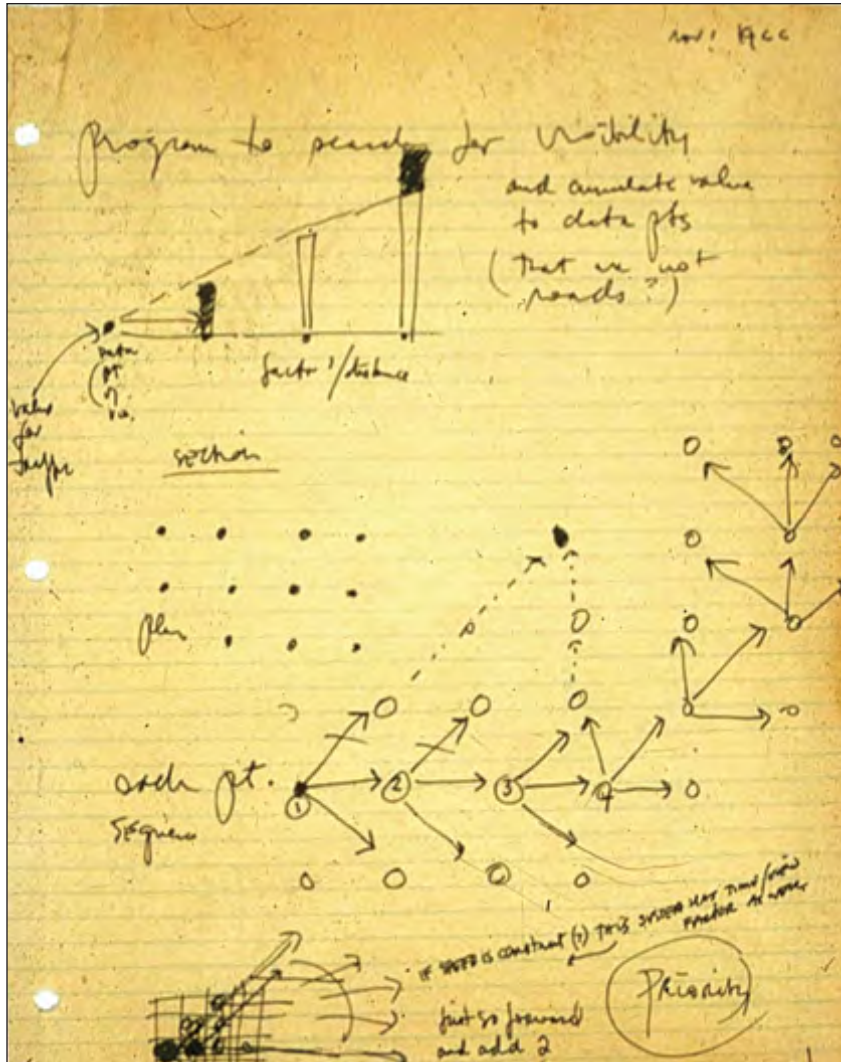


Figure 3. Ideas for analyzing networks, such as streets, and for assessing moving views in 3D, 1966.
(Courtesy of Carl Steinitz.)

a series of evaluation models for the future land uses under consideration. A design was made that was visually informed by the resultant maps (figures 4A and B).

To my knowledge, the Delmarva study was the first application of GIS-modeled evaluation to making a design for a large geographic region. It is worth noting that this earliest GIS work was accomplished using Hollerith cards and the line printer to make paper maps in black and white. My first regional-scale GIS map was based on hand-encoded data to a grid base measuring 2 miles by 2 miles. It cost \$35 (in 1965 dollars) for computing time on a \$2 million IBM machine, the only accessible computer at Harvard. A registered user was only allowed one computer use a day. How happy I was to produce my first basemap, finally, after 30 days of effort.

Yet even in this first study, some rather sophisticated analytic steps were undertaken. These included a gravity model; various terrain-related analyses; the effect of one map pattern on another; and overlay data maps combined via quantitatively weighted indexes, such as the relative attractiveness for vegetable or grain agriculture. I cannot overstate the importance of the initial academic decision of Charles Harris, then chairman of the Department of Landscape Architecture, to support me to introduce GIS-based computing in a design-oriented studio rather than in a specialized "technical/computer" course. This would prove crucial to the future development of GIS at Harvard as a set of methods for design.

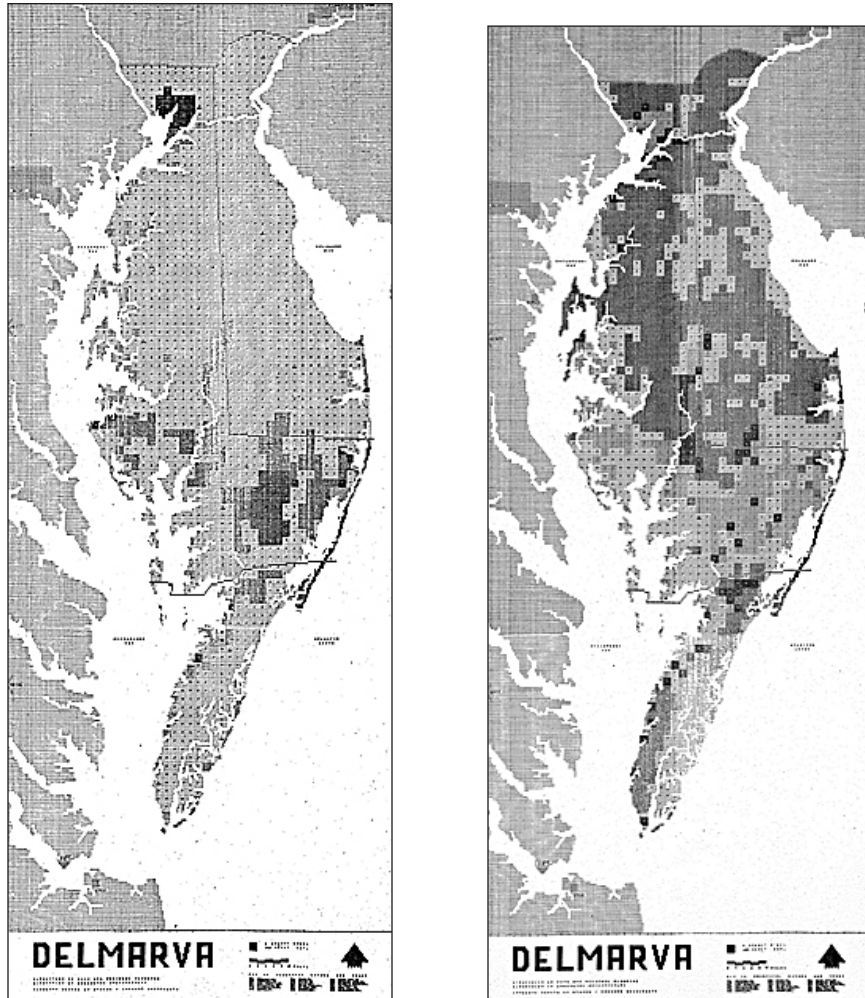


Figure 4A (left) and 4B (right). Data was combined using quantitatively weighted indexes to evaluate relative attractiveness for vegetable (left) and grain (right) agriculture.

(Courtesy of C. Steinitz.)

In 1967, Rogers and I organized and taught an experimental multidisciplinary studio on the future of the southwestern sector of the Boston metropolitan region. The intent was to model the often-seen conflicts between the environmental vulnerability of the regional landscape and its attractiveness for development. We were also making a regional design for better managing the region's sprawling urban expansion. My initial diagram for this study was made in early 1967 and is shown in figure 5. Note that it begins with an understanding of decision processes. It distinguishes between land-use demands and evaluations of their locational attractiveness and site resources and evaluations of

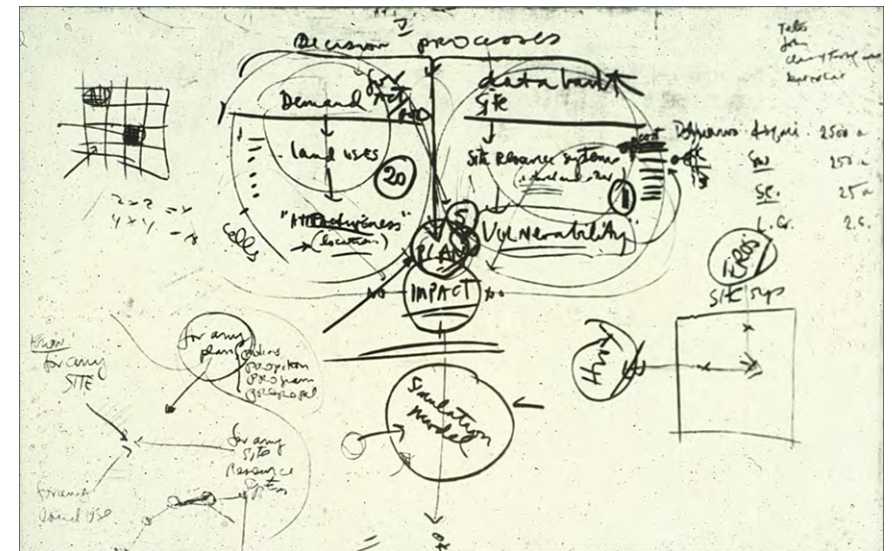


Figure 5. My earliest diagram for the information flow for a large-area design study, 1967.

(Courtesy of C. Steinitz.)

their vulnerabilities. It assesses risk and impacts and proposes generating plans with the rules of a simulation model. It is organized in the same sequence now outlined in the second iteration of the framework in my 2012 book *A Framework for Geodesign* (although we didn't call our work that at that time).

The entire flow of information for the study was designed by Rogers and me before any "work" was begun (figure 6). The study area was a rapidly changing suburban area. There was no digital data, so the students organized a GIS from air photo interpretation based on a 1-kilometer grid. (Remember, this was 1967.) Our students were also involved in all phases of the detailed specification, implementation, and uses of the models.

Ten process-related models were organized and linked, sharing what was then state-of-the-art GIS and programming software. Change was based on a demographic model that forecast population growth in different social classes and was allocated in 5-year increments for a period of 25 years. These created demand for new locations to accommodate industry, three residential types, recreation and open space, and commercial/institutional centers. This new land-use pattern then required new transport services. Four purposely different types of impacts were selected for assessment: local politics, local finances, visual quality, and water pollution. If these were deemed unacceptable by the students representing the decision makers, several feedback paths would result in redesign toward an improved land-use pattern for that stage. If the impacts were satisfactory,

the set of models would then be used to simulate the next 5-year stage.

The evaluation of attractiveness or vulnerability for each land use in the future was based on a regression model of the locational criteria for that land use in the present. Computer-made maps,



Figure 6. Peter Rogers (left) and Carl Steinitz at the Laboratory for Computer Graphics, Graduate School of Design, Harvard University, in 1967. Photographs of the process of working were taken only rarely, unfortunately.

such as the following evaluations of locational attractiveness for low-, medium-, and high-income housing, were made by SYMAP.

While we were certainly aware of computer-based allocation models at that time, we deliberately had our students conduct the change model (the phase that changed the geography of the region) by hand so that they would be as personally engaged as possible in the process. They made the allocations based on a smaller 250-meter grid, guided by the computer-generated evaluation maps.

These unit-areas of change were represented by color-coded cards for the land use to be allocated. The population model established the demand for each land-use type in a time stage, and then student teams, each representing different land uses, engaged in the physical and verbal process of competing for the most attractive locations, much in the way that an agent-based change model would function. They first simulated a future trend through the several time stages.

The students then assessed the consequences of the trend changes with the several impact models. These impacts were visualized by overlaying colored pins and notes on the causal changes. The students then interpreted the impacts and decided whether changes in the trend's land-use pattern of any stage were required. Lastly, they re-allocated the changes by design, producing results measured to be environmentally superior and meeting the criteria for development (figure 7). This Boston

study was published in 1970 as *A Systems Analysis Model of Urbanization and Change: An Experiment in Interdisciplinary Education* (MIT Press).

Also in 1967, our research group, which included landscape architects Richard Toth, Tim Murray, and Douglas Way and engineer-economist Rogers, began a series of GIS-based studies that related various ways of making and comparing designs for

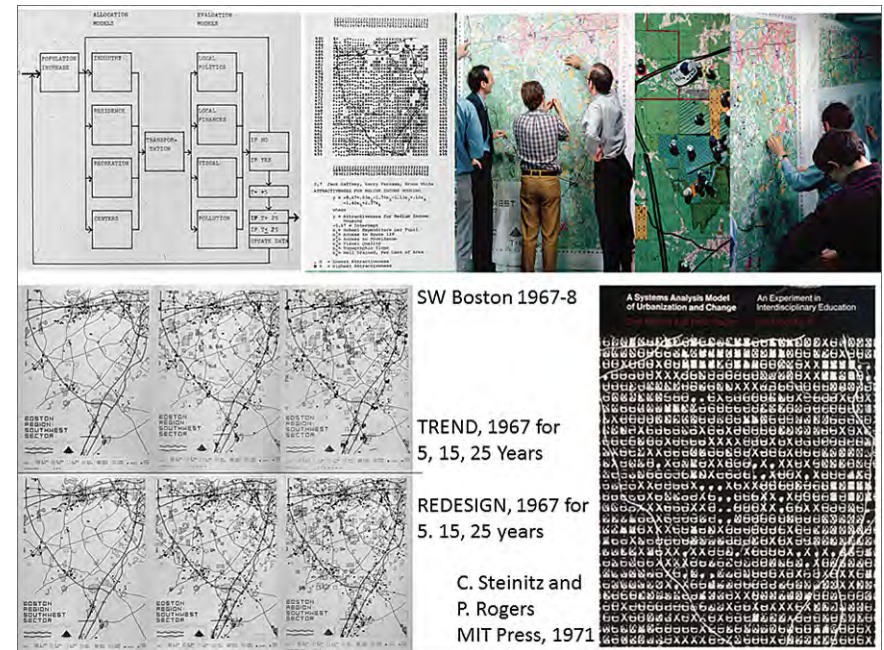


Figure 7. Upper: The structure of the study's 10 linked models, attractiveness for new middle-income housing, and allocating new development and conservation. Lower left: Trend growth (top three images) and improved growth (bottom three images). Lower right: Dust jacket of *A Systems Analysis Model of Urbanization and Change*, 1971.

large and environmentally vulnerable geographic areas with complicated programmatic needs. The Honey Hill study, named after its location in New Hampshire, was sponsored by the US Army Corps of Engineers. It involved a large proposed flood control reservoir and a new state park. GIS-based evaluation models were made of the attractiveness of this large area for recreation and other uses and of the vulnerability of the site's natural systems to harmful impacts. Each member of the research team then proposed a design for the new lake and park facilities, in summer and winter (figure 8). In addition, Rogers used a linear programming algorithm to produce a fiscally optimal plan.

These alternatives were all compared in yet another model, which simulated several levels of population demand and user movement to the area's facilities based on varied assumptions regarding number of persons and patterns of activity preference. Overcrowding and movement to second-choice locations or activities and capital and maintenance costs for the design alternatives were among the comparative impacts. Each design went through three iterations of assessment and redesign. The optimizing program performed best, and my design came in fourth.

This study provided important insights into the potential power of using GIS to link different model types and ways of designing to make better plans. This experience would shape our work for many years and, in my own case, to the present time. This research concept was the inspiration for a series of studies focusing on the Boston region in the late 1960s, as well as a major research program supported by the United States National Science Foundation in the early 1970s, which integrated GIS methods with sectoral models of the processes of urbanization and change.

Two additional early experiments may be of interest. In 1968, I designed a series of programs that automated the process of placing a series of prepackaged visual simulation forms for trees, houses, etc., on a raster terrain model and a land-cover map (figure 9). This program set then allowed one to specify the location and azimuth for a view or sequence (based on the work

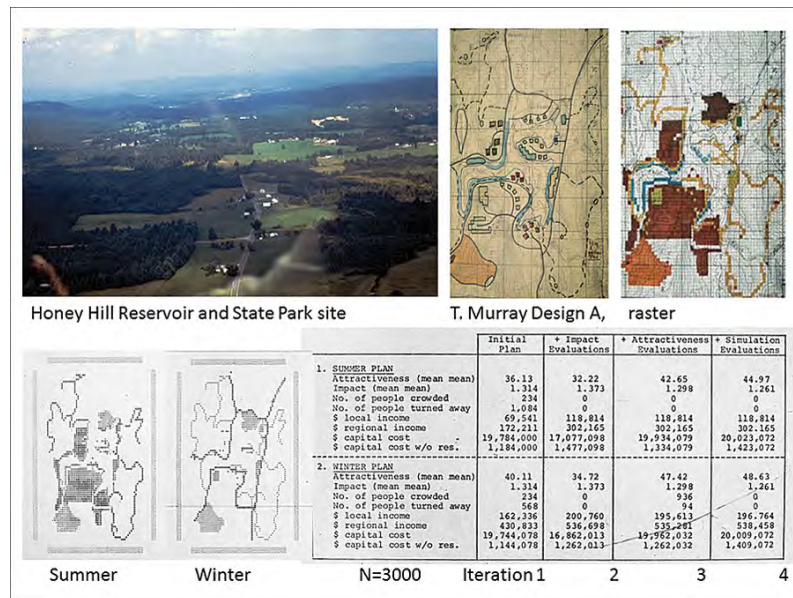


Figure 8. Top left: Aerial view of the site. Top right: Tim Murray's design. Bottom: Assessment of impacts of Murray's design.

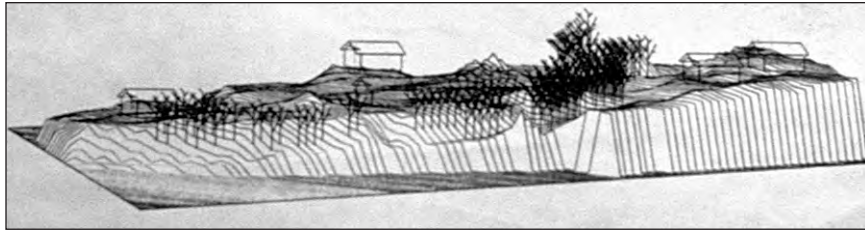


Figure 9. Buildings and trees on terrain.
(Courtesy of C. Steinitz.)

of Rens), and a pen plotter would painstakingly draw a series of perspectives in that GIS-generated landscape. The system was configured so that changes in the GIS terrain or land-cover map would automatically trigger changes in the landscape view. This technique was successful as an experiment but inefficient and uneconomical. It took several years before we efficiently linked GIS to automated allocation and animated visualization.

Also in 1968, and having made several experiments placing and visualizing a designed pattern of land uses on terrain, I had a series of discussions with architect Eric Teicholz about different ways in which rules could be established for the making of the designs themselves. We decided to make a series of experimental designs, which were rule based. There would be a street system and a pond, each with minimum setbacks; parking access within a minimum distance to every house; three housing types with prespecified locations for connections; and trees, which were allocated along roadways or near houses but could only be located on soil. The experiments varied the number of

houses among the three types and the number and roles of trees. Figure 10 shows the first experimental rule-based design.

In retrospect, I would divide these earliest years of GIS and its applications into three stages. In the middle 1960s, we used computers and computer graphics to do things we already knew how to do using noncomputer technologies. We acquired data and encoded it and produced maps. The analytic capabilities of the time were primitive, typically limited to applied studies on

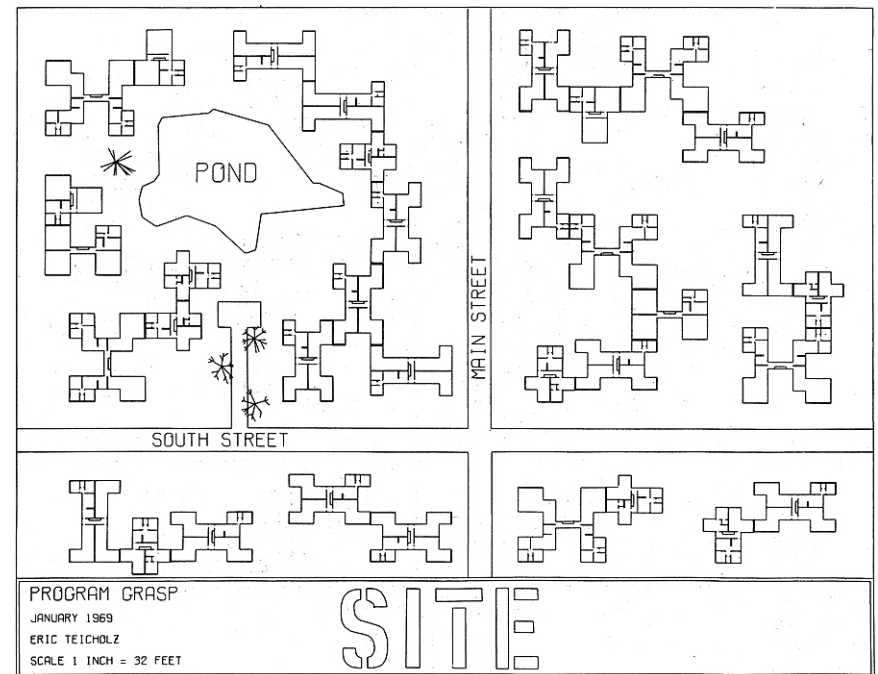


Figure 10. Our first experimental computer-generated, rule-based design.
(E. Teicholz with C. Steinitz.)

landscape classifications, sieve maps, or overlay combinations, all of which could have been accomplished with hand-drawn methods. Spatial and statistical analyses were difficult; professional acceptance was low, and public cynicism was high regarding analyses and the resultant graphics produced by computers.

The second stage, in the later 1960s, emphasized substantially more sophisticated GIS analyses: the merging of mapping and statistical techniques, the introduction of more sophisticated spatial analysis methods, and the introduction of graphic displays more diverse than two-dimensional maps. A strong research effort in theoretical geography was organized and directed by William Warntz and related to the theory of surfaces, the macrogeography of social and economic phenomena and central place theory.

During the third stage in the early 1970s, the laboratory saw important interaction with other disciplines and professions, particularly the scientific and engineering professions. We had the self-criticism that recognized the need for more predictable analysis and for better models. The view throughout this third stage was that information could and should influence design decisions. A critical professional role would be to organize that information, have it available and adaptable to questions, and thus provide decision makers with information relevant to decisions at hand. The focus on *aiding* decisions rather than

making decisions increased both public and professional interest and acceptance.

I ended my direct affiliation with the laboratory in this period. By then, we had developed, demonstrated, and occasionally linked and used computer software to fully support a variety of design processes. We had collaboratively applied these to significant studies of real, large, and complex places . . . the stuff of geodesign.

The laboratory continued to grow in size and influence under the further directorships of Warntz and Schmidt. The later 1970s to the mid-1980s may be characterized by the introduction of smaller and far less expensive computers, more user-friendly programs incorporating commands in common English or the ability to point a computer cursor, more easily acquired data, and a proliferation of analytic and graphics capabilities. These advances resulted in an increased potential for decentralized and networked computer use and in increased freedom from predefined analysis and planning approaches. However, the need—and responsibility—for selecting wisely from a much larger set of technical and methodological options also increased in this period. We saw in the universities and then in the professions the first computer-comfortable generation of students. Professional acceptance broadened, and computer use was no longer regarded as something special.

The Harvard Laboratory for Computer Graphics and Spatial Analysis ceased to exist—for many complex reasons—in 1981. By then, 165 people had served on the laboratory staff at one time or another. Much of the credit for the lab's diverse accomplishments should go to Fisher, who died in 1974 and who was a remarkable person of uncommon energy and foresight. The many individuals linked to the lab and their ideas, computer programs, demonstrations, publications, and especially students were significant contributors to the development of today's GIS and many of its applications, including geodesign.

About the Author

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Place-Based Knowledge in the Digital Age

By Thomas Fisher, Professor of Architecture and Dean of the College of Design, University of Minnesota

In Victor Hugo's *The Hunchback of Notre Dame*, the archdeacon holds up a book before the cathedral and says, "This will kill that. The book will kill the edifice."¹ Of course, we know that the printing press did not "kill" buildings. We still have cathedrals and books, and indeed, most books wouldn't survive very long unless stored in buildings.



But we also know that the book changed cathedrals, which had been thought of as "books in stone," with the stories of the Bible depicted in the statuary and stained glass of those buildings. We still have cathedrals today, but they no longer have to serve also as books, and so they have changed in fundamental ways, becoming more abstract in form, more diverse in function, and largely shorn of their didactic ornament.

I mention this because we find ourselves at another moment in time where we could hold up a digital device—a laptop, tablet, smartphone, or e-reader—and declare, in front of either a book or a building, that "this will kill that." While we know that such devices will not "kill" books or buildings for that matter, we have

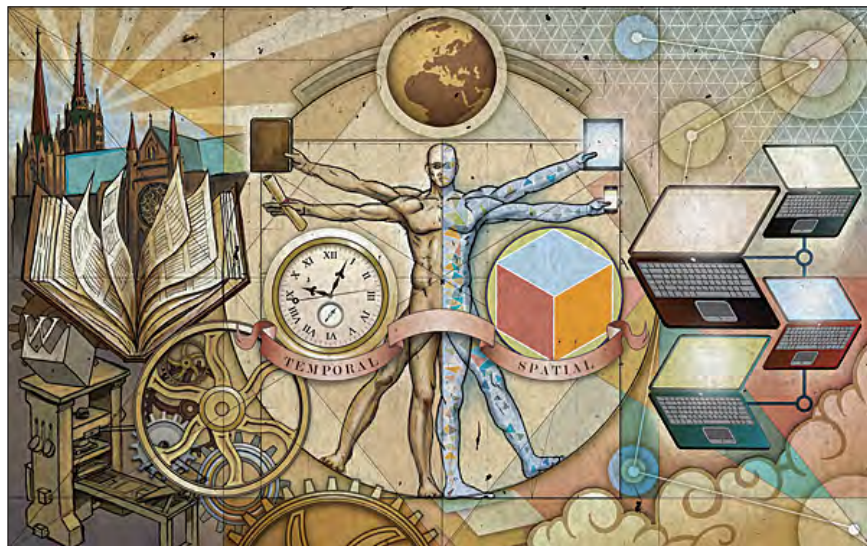
also gone far enough into the digital revolution to sense that digital media—and spatial media like geographic information systems—seem destined to have the same kind of effect as the printed book did beginning some 500 years ago.

This brings to mind the observation of Marshall McLuhan that each new technology "turns its predecessor into an art form."² Books will indeed survive the onslaught of downloadable e-books, but as we depend less and less upon books for information or even as the most convenient way to access information, we will increasingly value them as an art form, as McLuhan put it—as beautiful objects and works of great craftsmanship, exemplified in the rise of popular institutions such as the Minnesota Center for the Book Arts.

And what about Victor Hugo's claim that books ultimately trump buildings? Downloadable e-books have not "killed" the library as a building type, but as happened with the cathedral after the widespread adoption of the printing press, libraries have increasingly become places where people go to have experiences that they cannot find anywhere else. Like the modern cathedral, the modern library will likely have a greater array of functions; play a more social and less didactic role in people's

lives; and, at least partly, lose the primary purpose they once served of storing large quantities of books. It may be that, in the future, we will go to libraries to admire the craftsmanship of books and then interact with others about what we have learned from the information we have downloaded on our portable devices.

The biggest effect of the digital revolution, though, may be less material and more metaphorical. As McLuhan argued, the "medium is the message," with major changes in media leading to changes in our metaphors and to the meanings that we ascribe to the world.³ The mass-produced book led to a view of the world as a kind of machine, a metaphor that reflected the very thing that made this new media possible: the printing press. And that change in metaphor, in turn, led to many of the revolutions that



followed: the Protestant Revolution in the sixteenth century, the Scientific Revolution of the seventeenth century, the Democratic Revolutions of the late eighteenth century, and the Industrial Revolution of the nineteenth century.

The machine metaphor lasted well into the twentieth century and paradoxically gave rise to the very technology—computers—that would ultimately overturn that metaphor. In the early twentieth century, we still heard people talk about the world in mechanistic ways, with intellectuals like Leo Tolstoy calling the body "a living machine"⁴ and Le Corbusier calling the house a "machine for living in."⁵ Later in the last century, we still heard such mechanistic analogies, such as the physicist Stephen Hawking regarding the "brain as a computer."⁶

Computing, though, also gave us the Internet. And with that, along with the miniaturization of computing in mobile devices, we have gradually realized that computers represent not just a faster form of computation but an entirely new medium, which has brought with it a new metaphor that increasingly dominates our view of the world. It took machines, in other words, to move us from a mechanistic view of reality to a networked one. We no longer view the brain as a kind of computer, but instead as a neural network; no longer speak of society as a well-oiled mechanism, but instead as a social network; and no longer see the human body as a machine, but instead as part of the web of life.

This shift in metaphor matters even more than the media that has prompted it. We will, of course, continue to use machines just as we will continue to use books, and so our material world will remain layered with technologies of the past as well as the present. But when we start to think of ourselves and see the world differently, big things begin to happen, as we saw in the wake of the printing press. Human relationships and social structures change, as we have already seen in the "Arab Spring" revolutions taking place in areas like North Africa, fueled by the crowdsourcing capabilities of cell phone technology; in the micro-lending revolution in the developing world, enabled by the financial transfers possible through social networks; or in the green revolution going on around the world, empowered by our access to information formerly out of reach of ordinary people. The metaphor may ultimately be the message that matters.

The Ecology of Being

This metaphor of the world as a network or web will alter our intellectual lives as well. The old machine metaphor privileged physics, mechanics, and engineering—three of the fields most closely associated with mechanisms. The new web metaphor, instead, draws from fields like biology and ecology, seeing in their understanding of how natural ecosystems work a parallel to the networked world we now occupy and informing us about human ecosystems and how they relate to each other in particular places.

The increasingly weblike way of seeing the world, in turn, has profound implications for how and in what form we will seek information. The printed book offers us a linear way of doing so. We begin at the beginning—or maybe at the end, with the index—and work forward or backward through a book, or at least parts of it, to find the information we need. Digital media, in contrast, operate in networked ways, with hyperlinked texts taking us in multiple directions, social media placing us in multiple communities, and geographic information systems arranging data in multiple layers. No one starting place, relationship, or layer has privilege over any other in such a world.

The linearity of the book, compared to the multiplicity of the web, leads to an even more fundamental shift in how we assess reality: from a temporal to a spatial one. Like reading a book, we see time as an arrow, a linear path with starting and ending points. While we learned from Albert Einstein that we could slow time down depending upon how fast we accelerate, we cannot reverse time or occupy different speeds of time at the same time. But that is not the case with space. Like the web, we can manipulate space, move in multiple directions within it, and reverse it—tear a space down, for example—if we choose.

The worldwide web, of course, often seems aspatial. It connects us to people and places not in, and often far from, the actual spaces we occupy. Indeed, this new weblike way of engaging in the world appears to have collapsed both time and space, making everything that ever existed anywhere in the world

immediately available to us, as if temporal or spatial distance no longer mattered. Such effects, however, disguise the essentially spatial nature of digital media. The laterally linked and complexly networked nature of the web gives it a spatial form, conceptually if not always physically. And the layering of data and simultaneity of information through the web makes it place-based, even if that "place" exists in virtual space.

This line of thinking, in turn, suggests that the current way we store information—through digital documents and files—and distribute it—through e-mail, e-books, e-zines, and the like—may represent a transition stage in this technology. Such formats mimic the forms that emerged from the printing press and paper technology and, because of their familiarity, have enabled us to adapt to the access of digital information more easily. But they also reinforce a linear way of thinking about information inherently at odds with the weblike way in which we increasingly see the world.

GIS will eventually become a major way—perhaps the dominant way—in which we will access information in the future because of the essentially spatial nature of that software. Rather than see information as discrete bits, accessed linearly and temporally, like moving along a necklace of data, GIS layers information spatially, linking it according to its relevance to other data on a given layer and according to its relevance to all the other layers in a given place. It allows us to "map" information, which may become the

primary way we organize, access, and distribute knowledge in the future.

This use of spatial tools to match the spatial nature of a web will have a profound effect on how we think about information itself. The book led us to see information in highly discrete ways. By packaging related content between two covers, books encourage us to see knowledge as a set of distinct disciplines, each with its own discourse and eventually its own set of assumptions and use of language that made it increasingly hard for anyone else not in that discipline to understand. And by sorting information according to disciplines, books enabled us to think of knowledge divorced from any particular physical or conceptual space. As a result, we can take almost any subject—say, water—and find that topic addressed in myriad ways by many disciplines—the sciences and social sciences, literature and history, art and poetry—all located in different places in a library and all addressed in different ways through different disciplinary lenses.

That way of organizing knowledge has served us well in the last several centuries as we have sought to understand and control the world around us. But it's gotten in our way in recent decades, as we have come to realize the damage we have done to the world and the threat that that poses to our civilization and to us. It has led, for example, to what Adam Smith called the paradox of value, when he asked, at the beginning of *The Wealth of Nations*, why we so value diamonds that have so little real use, and why we don't value water, without which we cannot live.⁷ By dividing

information into discrete, disciplinary units, we have created what we might call the paradox of knowledge: in which we have so much information about the world and yet remain so ill informed about our effect on the world.

This suggests that we may need to arrange knowledge differently in the future, not according to disciplinary categories, but instead according to spatial phenomena and, as Smith would say, to the things without which we cannot live. GIS offers one way of doing so. While the data-rich digital mapping of GIS arose, initially, to ease geographic analysis and enhance spatial decision making, it has the potential to organize knowledge in ways that align more closely with the ways in which the world itself is organized: spatially.

That may make sense in spatially oriented fields, like geography, forestry, or planning, but how, you might ask, does that make sense for fields that appear to have no spatial equivalent: philosophy or pharmacy, history or histology, literature or linguistics? It's a good question, but maybe the wrong one to ask. It may be that we need to stop asking how to preserve our disciplines, which, for all their value, remain abstractions of or at best partial views of the world, and instead start asking how to preserve what remains of the natural world, which our disciplines, if they have any value, need to serve.



Spatializing Knowledge

How might GIS help us spatialize knowledge? Rather than organize knowledge by type or discipline, we could use GIS to embed all the knowledge relevant to a place in the myriad layers of information about it. And as we scroll over a place, we can select the pertinent layers and begin to see the relationships among disciplines and the connections among data. So many talk about the need for interdisciplinarity, but as long as we organize knowledge in disciplinary silos, the connections among disciplines will continue to elude us. When we instead begin to organize knowledge spatially, the connections come to the fore,

as we focus less on the layers and more on the overlay of them and on their relevance to particular situations.

This, of course, may seem too much to ask: the reorganization of knowledge and the spatializing of education. We have, however, managed over the last couple of centuries to temporalize education. Every field has a history, and almost every one requires that students study the history of the discipline as part of knowing it. Indeed, historical understanding has become such a part of what we define as an educated person that we take it almost for granted, but it wasn't always so. It wasn't until the nineteenth century that we assumed, as Georg Hegel argued, that we couldn't fully comprehend anything without knowing its history.

In the first decades of the twenty-first century, we need to see that the same holds true for space as much as it does for time. We cannot fully understand any field without also spatializing it, without also seeing how it relates to every other discipline as they come together in particular places, with a given group of people, in specific social and environmental contexts. We need to know how disciplines evolved over time, but we also need to know how they, so to speak, hit the ground and how they play out as part of the web that constitutes the whole of a place and of the people there.

This does not mean that we should see such spatial analysis as an end in itself. Except for historians, we rarely study

temporal phenomena—history—as an end in itself. In most fields, history serves as a means to an end, as a way of better understanding how the present came to be and what the future might hold. The same is true for a spatial understanding of our fields. Except for a few fields, like my own field of architecture, which does study space as an end in itself, most disciplines will likely see this weblike, spatial turn in our thinking as a means of understanding their subject in new ways. Space represents, like time, an a priori condition, as Immanuel Kant argued—a precondition to everything else, and so having a sense of the relationship of space and time—how a field evolved spatially as well as temporally, what happened where as well as when—will increasingly become necessary to fathom how we have done so much damage to so many places and to the cultures of so many people on the planet even as we purportedly know more about them.

The spatializing of knowledge via its mapping onto places has another advantage as well: it becomes a visual way of conveying information across the barriers of language and to the growing percentage of the human population that remains illiterate. The book divides the literate and illiterate and, as such, has helped reinforce the power of the former over the latter. Hugo understood that when he had the archdeacon hold up the book as killing the building. The medieval cathedrals spoke to both the literate and illiterate and, in some respects, the book made large stores of knowledge inaccessible to the latter.

The digital divide threatens that as well, with the wealthier parts of the world having much more access to information than the poorer parts. The web and cloud computing may help end that division by making most of what we need to know available at low cost, with "dumb" devices able to access information anywhere in the world. But there remains the problem of literacy, as well as translation, and so closing the digital divide through such devices will only partly close the gap that exists between those who have access to knowledge and those who don't.

We may never close the latter until we spatialize knowledge through the use of visual tools like GIS. Enabling people to see the information relevant to their lives, whether or not they can read, and to map it to the places they know to understand the conditions that affect their lives, could have a transformative effect in empowering those who have been left behind by the book and even by the early incarnations of the computer.

GIS may represent the leading edge of computer mapping and visualization technology, but it also signifies, in some respects, a return to the world that Hugo's archdeacon saw as threatened. This brings to mind the observation of the novelist and semiotician Umberto Eco—that modernism represented a premedieval condition, which suggests that our post-postmodern world may have more characteristics in common with the medieval world than we have recognized.⁸

If the medieval cathedral tells its stories in stone and glass, GIS tells them through layers and overlays. Both do so visually and spatially, both speak to viewers whose language or even whose literacy may not matter, and both reveal relationships and meanings that no book could ever capture. At the same time, the medieval cathedral and digital cartography both have the power to move us to action, to help us see things with our own eyes and without the interpretation of an author who might want to edit what we know or affect what we think.

Just as the book helped give rise to the Protestant Revolution, in which people wanted to read the Bible for themselves and make up their own minds, so too might the visual and spatial power of GIS someday give rise to a secular version of the same, in which people, protesting the power of a few to control so much of the knowledge about the world, will want to see that information for themselves and make up their own minds.

Geodesigning the Future

This leads to my final point about the spatializing of knowledge. The temporalizing of knowledge has, through the agency of history, helped us understand the past and possibly comprehend how the present came to be, but rarely do we venture very far into the future. We call that science fiction or fantasy to set such future-oriented thinking apart from what we can reliably know about the world as it is or as it once was. And we tend to see

such work as somehow of lesser quality or validity than what the sciences, social sciences, and humanities offer.

But spatial understanding has a different relationship to the future, as well as the past and present. Spatial knowledge recognizes place, rather than time, as the ultimate continuity in our lives. And while none of us can see the future as a temporal idea, we continually imagine the future of places, projecting possible spatial arrangements based on what we see around us.

The design disciplines do this all the time, using spatial means to imagine what could be, envisioning the future of a place, product, or environment, and depicting that visually for others to see. We commend or criticize a design and accept or alter it to fit our idea of what should happen in a particular place or with a particular product. We don't consider design a lesser discipline, simply a different one, operating according to its criteria and assumptions.

I mention this because the leading edge of GIS rests with the idea of "geodesign," the use of geographic analyses of what is as the basis of making design decisions about what could be. Rather than see future-oriented thinking as somehow fiction or fantasy, geodesign allows us to connect what we know about the world with what we might want the world to be. Just as GIS can serve as a means of organizing knowledge spatially, geodesign might serve as a means of projecting that knowledge into the future and assessing its merits based on what we know about a place.

Why does this matter? Because we stand on a similar precipice as Hugo's archdeacon, with even more drastic implications. We might well say that "this will kill that," but in our case, "this" represents modern civilization and "that," the natural world. Since the rise of the book, although not necessarily because of it, we have devised a Ponzi scheme with the planet over the last couple of centuries, exploiting natural resources, other species, foreign cultures, and even future generations to keep those at the top of this pyramid scheme enriched.

As we know from the collapse of other, smaller Ponzi schemes, such frauds cannot last. They tend to collapse suddenly and without warning, and those most enriched by the scheme—us—have the farthest to fall. The only way we can avoid such a fate is to realign our relationship with the natural world, to reorganize our considerable knowledge about it to reveal the forces that lead to our unsustainable practices, and to relearn how to steward what remains of the planet we have so altered. And if we don't, we have only to alter the terms of Hugo's observation only slightly. *This*—the collapse of our Ponzi scheme—will kill *that*—the civilization we have built up over the last 200 years.

The spatialization of our knowledge, in other words, isn't just an academic exercise or the result of some arcane interest of a few spatial thinkers or GIS specialists. With it, we can begin to set the foundation for a more sustainable future for ourselves as we see the impact of our actions and the relevance of our knowledge to the particular places in which we live. This will not kill anything

except the ridiculous illusion that we can continue to live beyond the carrying capacity of our planet. And doing so is not just about space; it's about time!

About the Author

Thomas Fisher is a professor in the School of Architecture and dean of the College of Design at the University of Minnesota in the Twin Cities. This paper is based on Fisher's keynote address to the GeoDesign and Spatializing the University meeting of the Big 10 university librarians, May 2012.

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(This article originally appeared in the Fall 2013 issue of ArcNews.)

Geodesign Pioneer Honored

by Karen Richardson, Marketing Writer, Esri

[Dr. Stephen Ervin](#) is as vibrant as his day of birth—[Mardi Gras](#). Like the celebratory day itself, Ervin is animated, larger than life, and full of contagious energy. He has spent two decades working at Harvard University teaching courses, speaking at conferences, and authoring books about his passion—the intersection of computing, design, and science. "Geodesign has taken over my life," Ervin chuckles.

The Assistant Dean for Information Technology at Harvard's [Graduate School of Design](#), Director of Computer Resources, and lecturer in the Department of Landscape Architecture, Ervin still somehow manages to find time to evangelize and promote the principles of [geodesign](#) in various ways around the world.

"When I first heard the term, I thought I'd been using it all my life," said Ervin. "But I hadn't. There was no geodesign 50 years ago. We finally have the means to go about geodesign with all this digital technology—computers and software and satellites and collaboration tools, apps and smartphones—we have a whole new discipline on our hands."

A Defining Moment

In Ervin's opinion, geodesign is something that has been talked about for many years. "We called it computer-aided design," said Ervin. "We didn't mean CAD—we meant design aided by computation, and that's really where we are headed."



Stephen Ervin (right) accepts the prestigious Lifetime Achievement Award at the 2012 Esri User Conference for his pioneering work integrating GIS and design.

One of the defining moments in Ervin's career was studying in the graduate school at the University of Massachusetts in Amherst, Massachusetts in the landscape architecture program, which introduced Ervin to computer representations of the real world. "I saw this image of ski slopes cut into the hills and the forest clearing that were quite primitive graphically; at that time trees were little triangles with sticks," said Ervin. "It probably cost days and thousands of dollars for the US Forest Service to produce back in the 1970s. I was drawn to this idea that took bits and bytes and tabular data about tree positions and species and an elevation model and turned it into a visual representation from which decisions could be made."

The idea that data could be combined with graphical representations was inspirational to Ervin, and shortly after he was introduced to GIS at Harvard University's Laboratory for Computer Graphics and Spatial Analysis. In 1984, Ervin took this knowledge and began a software company to help landscape architects visualize the results of design decisions.

The Future of Geodesign

At the 2012 Esri [User Conference](#), Esri president Jack Dangermond presented Ervin with the prestigious Lifetime Achievement Award for his pioneering work in melding together the disciplines of GIS and design. In presenting the award, Dangermond noted that "lifetime" didn't mean that Ervin's work was done. There is still much important work to do.

[View Ervin's presentation on the future of geodesign from the 2012 Geodesign Summit.](#)



Ervin sees the marriage of science and design as the real challenge to geodesign, so interactions may be orchestrated and we can see the true impacts of design decisions. The idea that people can have visual feedback for decisions—such as with the ski slope representations—has become a fundamental driver to what Ervin finds the most exciting about geodesign. "The idea of immediate visual feedback and dashboards to display key indicators that tell us how well we're doing, and in real time, is important," said Ervin. "Whether measuring carbon footprint or total costs or total number of houses, cars, buses or even elephants—it's important to have this kind of feedback and in real time."

(This article originally appeared on [August 22, 2012](#), in the *Esri Insider* blog.)

The Geoscape: A New Canvas for Understanding

by Matt Artz

For many years, Bill Miller directed the development of Esri's training and support infrastructure. Later as an engineer/architect, he was intimately involved in the design of Esri's state-of-the-art corporate headquarters and conference center. Perhaps his best-known contribution to the GIS community was development of the ModelBuilder environment released as part of the ArcGIS Spatial Analyst extension. More recently, he came out of retirement to rejoin Esri and head up a new Geodesign Services effort.

Miller's [vision](#) for the integration of geospatial technologies with the design process was long shared by a group of people that included UC Santa Barbara's [Michael Goodchild](#), Esri President [Jack Dangermond](#), Harvard University's [Carl Steinitz](#), and a handful of others. Miller took the first step towards making this vision a reality when he assembled a small team to develop ArcSketch, a free sample extension that allowed users to quickly sketch features in ArcGIS. ArcSketch was Esri's first small step toward what is now commonly referred to as "[geodesign](#)."

Beyond Landscape

While identifying the technology hurdles the geospatial industry needed to overcome in order to advance the concept of geodesign, Miller noted a fundamental contextual obstacle as well: our traditional approach to abstracting the landscape severely limited our ability to move forward with geodesign. We couldn't fully realize the vision of geodesign without a framework for a more holistic, comprehensive understanding of the world around us.



Bill Miller shares his vision at the 2012 Geodesign Summit.

Different levels of understanding often require different levels of abstraction, and it's clear that's what was happening with geodesign. As TED founder Richard Saul Wurman has so succinctly stated, "Understanding precedes action." Design is action. Before we can design, we must understand. Geodesign—the act of thoughtfully creating the future for the mutual benefit of humans and the natural environment—requires a heightened level of understanding.

Understanding the world for the purpose of geodesign necessitated extending our view of geographic space. "This meant moving from 2D to 3D and to 4D, coupled with the idea that most data, at some level, is spatial and that all types of spatial data (physical, biological, social, cultural, economic, urban, etc.) can be geo-referenced," states Miller. "This ultimately led to an expanded view of what is typically envisioned, or imagined, when referring to the *geo* portion of *geodesign*." He likes to call this new context for understanding our world "the geoscape."

A New Context

Extending our traditional methods of abstracting the landscape to include 3D "provides us with the ability to geo-reference what lies below, on and above the surface of the earth, including what exists inside and outside buildings, as well as 4D geographic space, or how things change through time," Miller notes. "This gives us the added ability to geo-reference time-dependent

information such as population growth or the migration of a toxic plume through a building."

Miller defines the geoscape as the planet's "life zone," including everything that lies below, on, and above the surface of the earth that supports life. The geoscape expands the view of what constitutes the content of geography as well as the dimensional extent of the geographic space used to reference that content. It gives us the context we need to actually do geodesign, "ensuring that our designs consider everything that supports or inhibits life."

Designing a Better World

The concept of the geoscape gives us the framework to extend our thinking and understanding of the world around us. As we move from thinking about only the surface of the earth to now including what's below and above the surface, we take into consideration the full spectrum of the earth's life support system. This represents a significant transformation in the way people think about geography, geodesign, and the application of geospatial technologies.

The geoscape gives us a new canvas for understanding, moving beyond traditional mapping for navigation and location, towards using our maps for active designing and decision making. Moving from the landscape to the geoscape gives us the canvas we need for designing a better world. After all, as Miller is fond of saying, "The purpose of design is to facilitate life."

Read Miller's new paper, "[Introducing Geodesign: The Concept.](#)"

About Matt Artz

[Matt Artz](#) joined Esri in 1989. In his current role as GIS and Science Manager, he helps communicate the value of GIS as a tool for scientific research and understanding. He writes extensively about geospatial technologies, manages the GIS and Science blog, and is the editor of GIS.com. Prior to joining Esri he worked as an Environmental Scientist at a large science and engineering consulting company, on such diverse projects as highway noise modeling, archaeological impact assessment, and chemical weapons disposal. His educational background includes an M.S. degree in Environmental Policy and Planning and a B.S. degree in Anthropology and Geography.



(This article originally appeared on [July 30, 2012](#), in the *Esri Insider* blog.)

Geodesign Tackles Big Problems and Brings GIS into the Design Fields

Four years ago, designer and technologist Bran Ferren issued a challenge during the first Geodesign Summit: become better storytellers using [geodesign](#).

Ferren, the chief creative officer of Applied Minds LLC, returned to Esri in January to keynote the fourth [Geodesign Summit](#), reiterate his first call to action, and deliver another: [develop a 250-year plan for the planet enabled by geodesign](#) to create a vision of the future.

"Geodesign combines geography and data with modeling, simulation, and visualization to tell stories and [show] the consequences of your actions," Ferren told the more than 260 architects, urban and transportation planners, GIS and design professionals, educators, and others, in attendance. He sees great potential for geodesign to ultimately help find solutions to complex problems. "It is still in the shiny object stage, but it will be very important," he said.

Geodesign technology will mature naturally, much like other technologies, such as GPS, did. But meanwhile, said Ferren, in this era of short attention spans, people need to start thinking far, far into the future to create a problem-solving template that



The fourth Geodesign Summit in the Esri auditorium.

can be built on over time. "If we are going to address these big global issues facing us—whether that's disease, education, freshwater, war, or global warming—you actually have to take a long view," Ferren said. "For this planet, we need—pick a number—a 250-year plan."

Ferren said questions need to be posed, such as the following:

- What is your current state of affairs or the topic you are worried about?
- What is your desired end state?
- How are you going to get there?

"I argue that just having the discipline to sit down for a day and think about that will change your whole thought process," Ferren said. "It doesn't mean you are going to know exactly what the future is, but having a sense that in 250 years you would like to address these things at least gives you an intellectual template and road map to test your ideas against."

This process will be collaborative, too, according to Ferren.

"That's the power of geodesign," he said. "It's this network extension of shared intelligence where the insights of individuals can be shared among others and that can be used as the foundation to build upon."

Ferren also said that geodesigners in the future will be entrusted with the same power over life and death that doctors have today, because the decisions they make will be critical to humans and other species. "The mistakes you make in planning and designing our cities may take 100 years until someone understands the consequences of those actions. The Hippocratic Oath for geodesign: First, do no harm," he said. "Understand what you are doing and the effect; if you know this is going to do long-term

damage, it is not okay to do it. We aren't on this earth very long. It's a mere blip. Try to leave it a little better than how we found it."

Technology Matters

Summit attendees also heard from Esri president Jack Dangermond, who spoke about his enduring belief in technology as an agent of positive change to tackle the planet's big problems. "In my life, I always believed technology could matter," he said.

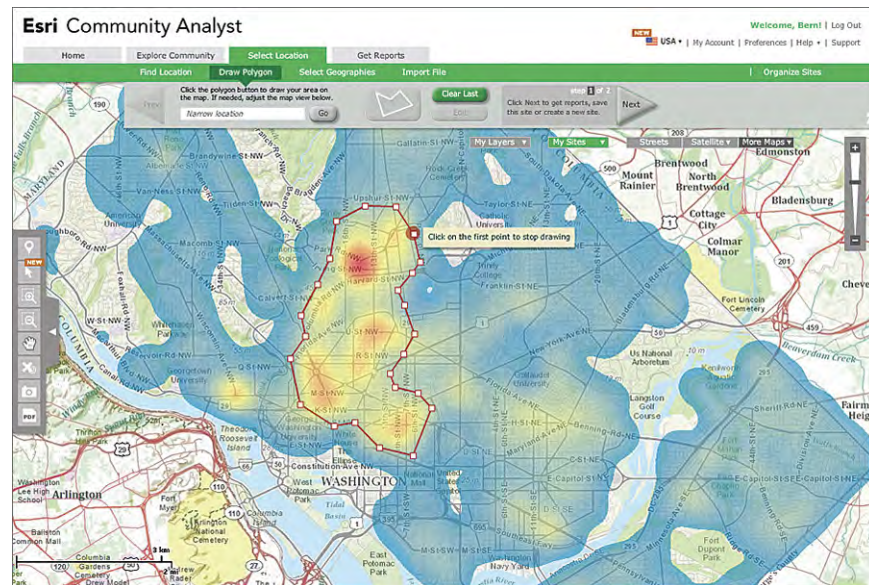
He also spoke about a shift, with GIS becoming a platform technology that's more participatory than ever before because it is now widely available via a cloud gateway that supports applications on the web and on mobile devices.

"This potentially has the power of making the concepts of geography, the models, the analytics—not simply the visualization—available to everyone," Dangermond said.

For organizations, this means that geographic knowledge—including geodesign tools—will become available to a much wider audience than in the past.

This idea of GIS as a platform was brought home to the audience with demonstrations that showed the increasing simplicity of making online maps using [ArcGIS Online](#) and [Esri Story Maps](#) templates. Esri staff also gave short demonstrations of [Community Analyst](#), which is used for mapping demographic,

health, and other data, and Esri landscape analysis services, a new set of data services (still being tested in beta) geared specifically toward geodesign work.



The [Community Analyst geodesign tool](#) can be used to glean information about a variety of community/people focused demographic data and reports.

For his demonstration, Esri technology evangelist Bern Szukalski used Esri landscape analysis services to study the siting of the Ivanpah Solar Electric Generating System, currently being built in the Mojave Desert. He used Esri landscape analysis tools to study the solar power-generating potential at the site, the slope of the terrain, and critical habitat areas for desert tortoises in proximity

to the solar project. Esri landscape analysis services are well suited for regional planning projects to study various scenarios.

Modeling the Future

Another geodesign-related technology demonstration showed how Esri technology was used to model the impacts of transit-oriented development in 3D for the city of Honolulu, Hawaii (see "[3D Modeling Shows Off Elevated Rail System Landscape](#)").

With the city's population expected to increase by 164,000 people by 2050 and traffic congestion a problem now, Honolulu faces major development decisions.

Esri solutions engineer Eric Wittner showed how Esri software was used to model alternative futures for Honolulu. First, GIS information, prepared using Esri [ArcGIS for Desktop](#), and 3D GIS data from Pictometry and PLW Modelworks, which represented realistic building models for portions of the city, were combined in [Esri CityEngine](#). CityEngine is 3D modeling software for urban environments.

Using a set of rules, a 3D representation of the city as it looks now was generated in CityEngine. Then the software was used to model different scenarios of how the city might grow.

One scenario showed significant urban sprawl if thousands of new single-family homes were built outside the urban core. Another 3D model showed much less of a footprint in

undeveloped areas if the city built up with people living in tall buildings near a multibillion dollar light rail system currently under construction.

These technology demonstrations were inspiring to many Geodesign Summit attendees, such as Juan C. Perez, director of transportation and land management for the Transportation and Land Management Agency, County of Riverside, California.

"The session that focused on the visual modeling and analytic tools when presenting land-use decisions to policy makers was excellent," Perez said, adding that he would like Riverside County to use some of the tools.

Perez also said Ferren's proposal of a 250-year plan was thought provoking. "While perhaps extreme at first blush, it really puts into perspective that the land-use decisions that we make have very long-term consequences."

The Instant City

Elliot Hartley, a director of Garsdale Design Limited in Cumbria, United Kingdom, gave a talk called "[The Instant City—Geodesign and Urban Planning](#)." His firm, along with its Iraqi Planners Group, is creating a master plan for the city of Nasiriyah, Iraq, which includes plans for future housing, utilities, and infrastructure. Garsdale used the capabilities in Esri CityEngine, 3D modeling software for urban environments, to change the plans when new data was added or late changes were made.

Work that took four days using other software took only a half day using CityEngine, he said (see "[CityEngine Creates New Solutions for Historic Cities](#)").

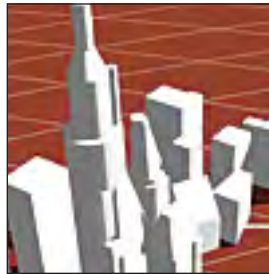
For more information, visit geodesignsummit.com.

(This article originally appeared in the Spring 2013 issue of *ArcNews*.)

Agents, Models, and Geodesign

By Michael Batty, Bartlett Professor, University College London

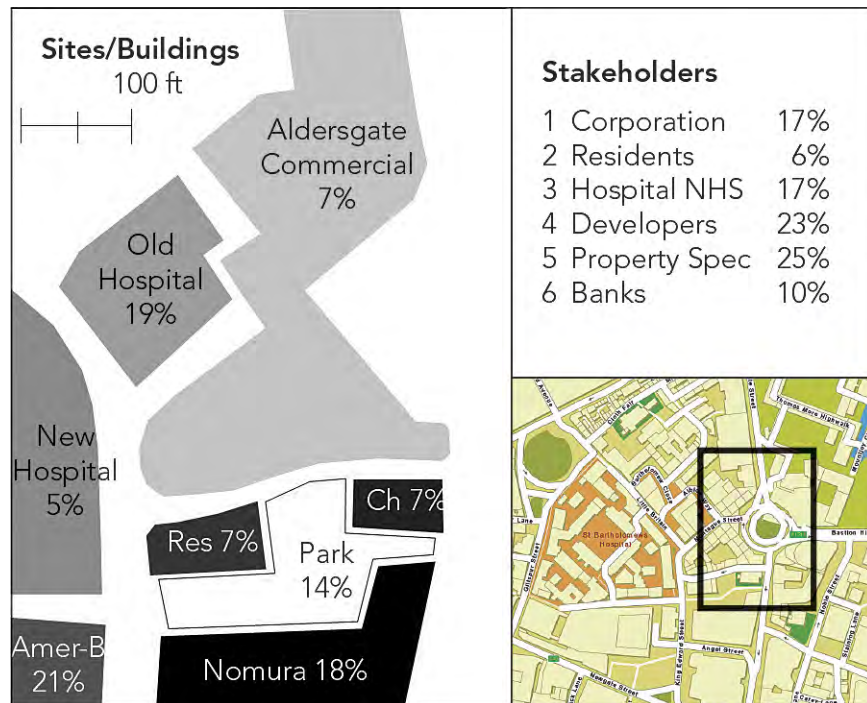
Michael Batty explains how the process of [geodesign](#) might be compared to one in which conflicting views about a spatial design can be systematically resolved in moving to a solution by using a simple network model of conflict resolution. Such models assume two sets of agents—designers or stakeholders, as well as land parcels or locations—incorporated with attributes of suitability that the stakeholders use to reach a consensus over the best design. He illustrates the idea with a "toy" problem of the redevelopment potential of eight sites in central London that are influenced by six distinct stakeholders.



There are now many new methods for modeling cities that differ from the traditional approaches to simulating urban structure, land use, and transportation flows. As data has become richer and bigger and computers have become all-pervasive, with ever-increasing memories and ever-faster processing times, it has become possible to model the behaviors of individual objects that make up data aggregates, such as populations, that were the focus of simulation models a decade or more ago. Individuals that compose these populations can now be represented as

distinct objects within computations, now usually being referred to as *agents*. Agents are essentially individual objects that have to be well-defined with strong identities and distinct from the environment in which they sit. These might be likened to the "atoms" that compose our cities, notwithstanding that what goes on inside the atom is hidden from our view. Although in cities agents are often considered to be human beings, it is quite possible to define them in terms of any distinct objects that compose a system. In particular, agents might be streets or buildings, components that make up the weather or vehicles on the highway, the bricks that a house is built from, or the pipes/wires that click together to keep our utilities functioning. Their definition is entirely dependent on the context, and in this sense, agent-based models or modeling (ABM) has emerged as a much more generic tool for simulation than most of the other approaches developed hitherto. Indeed, Esri has introduced a plug-in called [Agent Analyst](#) that enables users to build agent models that have a spatial component, which is the map in ArcGIS.

The easiest way to introduce ABM would be to illustrate a model of moving cars on a highway or pedestrians on a street. Agents in this case have mobility, and the focus of simulation would be the dynamics of how they behave and how they cluster and spread out. There are many models of this kind linked to spatial environments that are presented using GIS. But here we will change the focus and develop a model for illustrating how the



The Sites and the Stakeholders—The location of the area is shown in the inset at the bottom right, while the ultimate importance of each site for redevelopment and the power of the stakeholders in determining this are shown as the percentages in the figure.

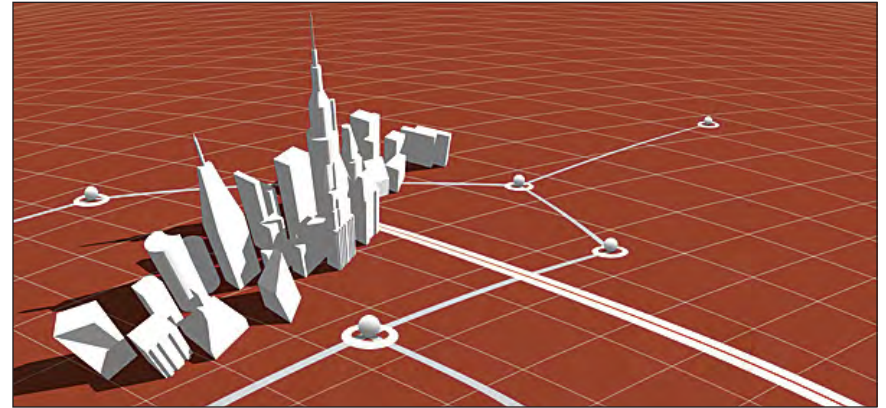
agents who are actually involved in the design process itself communicate with one another in the effort to reach a collective decision. Our model will be about how designers design rather than how they use their knowledge of cities and their environments to generate decisions. We are thus transferring our focus to the design and decision process itself, and we will show how a model can be built that enables us to articulate the way those involved in design communicate and pool their ideas and opinions about what is the best design.

In fact, the model of how geodesigners or the stakeholders who are involved in the design and decision process communicate with one another is rather simple to explain. Essentially, we assume there is a network of relations between stakeholders, which is a structure based on how close, in terms of ideas about the design problem, they are to one another and how likely they are to communicate. The network connects everyone to everyone else, some directly, but most indirectly. The process works as follows. At each time period, those agents who are connected to other agents send their opinions to those agents to whom they are directly connected across the network. When the agents receive the opinions of those to whom they are directly connected, they make a rational compromise: they change their own opinions to an average of those they receive. They then take these new averaged opinions and communicate these using the same network at the next time step. They then average the averages in the second round. If they keep doing this, the initial

differences between the agents will be reduced, and eventually everyone will hold the same opinion. Consensus reigns in the form of a weighted average of all the differing opinions. If the problem is suitably framed, then this consensus can be seen as the design solution.

Of course, you might object that in any design problem, this kind of consensus could not be ensured. Links in the network might be absent, meaning that some agents never pass their opinions to others. If opinions are passed, the agents may not decide to consider them. There are many ways in which communication may fail or be blocked, distorted, or manipulated. But if a design is to result, then some sort of compromise of conflicting or differing views about the best design must occur. Moreover, this idea of a network could be the basis for the design of a process that would achieve consensus—that is, of designing a network that enables the right kinds of communication to take place from which the best solution is guaranteed. Now this, of course, is an ideal type. This model of agents who are geodesigners in the broadest sense of the word is what we might hope for, but it can be made operational, and it is a point of view that forces us to consider how geodesigners design and converge to an agreed solution.

To illustrate it, let me pose a hypothetical problem that we have studied in London's financial quarter, or the "square mile," where we have identified a typical problem of change and redevelopment of land use and building form that requires the



agreement of several key stakeholders. This involves a cluster of buildings composed of residential, commercial, and hospital uses where we show and label the sites in question in the above illustration. This is a toy problem, but it could easily be scaled up to include many building parcels and land uses and many different stakeholders. As in any specific context, the model only comes into its own as a useful way of exploiting geodesign once we do scale up, and thus our toy model simply illustrates the method.

The area for our design is around the original location of the central post office adjacent to St. Paul's Cathedral and the new London Stock Exchange in central London. This is the notional center of the UK postcode districts. Here, Marconi sent the first public wireless signal in 1896, and John and Charles Wesley founded Methodism in 1738 in the street known as Little Britain. The area is composed of eight key sites: the Bank of America/

Merrill Lynch and Nomura Bank, which occupy two of the old post office buildings sold off to the private sector in the last 20 years; a residential block built recently; two buildings of St. Bartholomew's hospital, one of these just reconstructed and one ripe for redevelopment; a small Georgian church called St. Botolph's; a large commercial block recently developed; and a pocket park of enormous charm. If you want to look at the problem more graphically, then see [the PDF of my slides](#) given when I presented a similar talk at the recent 2013 Geodesign Summit. We can now define six key interest groups—stakeholders—that all have some stake in whether or not these eight sites need to be redeveloped and/or change their use, which would involve some alteration to their building fabrics. The stakeholders are the hospital, in the form of the National Health Service; the residents; the banks; property speculators who continually dwell on high-value sites, such as those in this problem; developers anxious for lucrative redevelopment contracts; and the City Corporation (the municipality), which acts as the basic arbiter of all development in the city. Now each of these agents has a view about whether or not each of the eight buildings should be converted or redeveloped. If we then record these views as being in favor of change (1) or against it (0), then we can assemble a matrix or table where the rows are the stakeholder agents and the columns are the land parcels or sites, a second and different set of agents. We can show this level of interest as in Table 1 below, where each row is the interest (1) or

disinterest (0) the relevant stakeholder has in the redevelopment potential of the building parcel.

Stakeholders	Buildings	Aldersgate Office	St Botolph's Church	Nomura Bank	Residential	Postman's Park	Bank of America	Hospital New Build	Hospital Old Build
City Corporation		0	0	0	0	1	1	0	0
Residents		1	1	1	1	1	1	0	1
Hospital NHS		0	0	1	0	1	1	1	1
Developers		0	0	1	0	0	1	0	1
Property Spec		0	0	0	0	0	0	0	1
Banks		0	0	1	0	0	1	0	1

Table 1.

Now, this matrix or table contains all the salient information about the design problem. This, in fact, is a set of maps. If you look at the table from the vantage point of each stakeholder—across each row—then each is a map of what the stakeholder thinks should be done in each parcel. One could easily imagine each row as constituting a set of grid squares from a 2D map splayed out as a vector rather than a grid or other 2D arrangement of sites. The second problem is defined when we look at each column, which is a set of what each stakeholder's interest is in any particular site.

Now, the problem as we posed it involves each stakeholder taking the map and pooling it with those to whom they are connected in a network. However, we have not yet been at all specific about what the network is, but one way of defining it is from the above matrix. If we pose the question, How related are each of the stakeholders to each other with respect to their maps? then we could relate each row/stakeholder to any other by simply counting the number of common links. We can arrange this as an interaction matrix, and this can act as our communications network, with the strength of the links giving the importance of the communication for the pooling or averaging of maps. To give an idea of this interaction, the network between the stakeholders can be easily derived by counting in the way I have explained as shown in Table 2.

							Σ
City Corporation	3	1	3	3	3	1	14
Residents	1	1	1	1	1	0	5
Hospital NHS	3	1	3	3	3	1	14
Developers	3	1	3	5	4	2	18
Property Spec	3	1	3	4	7	2	20
Banks	1	0	1	2	2	2	8

Table 2.

The sums (Σ) of the interactions given at the end of each row must be divided into the entries to get the fractional network weights. Now for the action—for the way the agents interact in

moving to a consensus. We can swap each map (row in the initial matrix) for all the other maps linked to each agent in the network mentioned above and then average these maps—the opinions of stakeholders to whom each agent is linked—using the strengths of the links as weights. So for the City Corporation, the new averaged map showing the corporation's new interest in the sites is formed by setting the weights proportionally to the strengths of the connections. So this would be 3/14, 1/14, 3/14, 3/14, 3/14, and 1/14, noting that these weights add to 1 to make the average of the maps of the stakeholders to which the corporation is linked. If we keep on averaging for all stakeholders in this manner, then eventually each map will converge to the same interest that each stakeholder shows in each site, and this would converge to the following values of interest, where we note that we have scaled these degrees of interest in each of the eight sites to add to 100: 7, 7, 18, 7, 14, 21, 5, and 19.

Now, this decision process gives us weights that each stakeholder can apply to produce an average map. But there is another process we might consider as the dual that involves us in averaging each site against each other site in terms of the weight associated with each stakeholder. We count the number of common stakeholders with respect to each pair of sites from the first matrix above, and this gives us another network—a dual network—which is generated as strengths of interaction between the sites. In this sense, the site might also be seen as an agent. If we average on sites with respect to the different views

of stakeholders, eventually the same sort of convergence occurs, and we can then find the importance of each site as making up the consensus of the stakeholders. The values we get for each of the stakeholders from the averaging of sites when consensus is reached is as follows, noting again that the values are scaled to add to 100: 17, 6, 17, 23, 25, and 10.

What all this means is as follows: For the first problem—the so-called primal—we work out a probability that each site should be redeveloped for change of use, which is agreed by all stakeholders, and this occurs when they reach a consensus by successfully changing their degree of interest sequentially. For the dual problem, each stakeholder is given a degree of importance in the problem, which is due to the fact that there is convergence on the value of each site.

Now, I appreciate that this is a huge mouthful of ideas to absorb. I have not produced many graphics here to explain it blow by blow, but the map above shows the eight sites in question as land parcels and their relative importance and also tables of the stakeholders and their relative importance in determining the importance of the sites. What this shows is that the property speculators and developers have much more importance in influencing the outcomes of redevelopment than the residents or even the banks. In terms of the eight sites, the most important with respect to a change of use are, first, the banks that acquired the old post office sites and are now subject to financial problems—hence their current decision to lease out

these buildings—and second, the old hospital site. The Georgian church is protected, and there is little enthusiasm to redevelop the newly developed hospital site, the existing Aldersgate offices, and the residential block, all of which have been renovated and/or rebuilt in the last 15 years. The park is intriguing, as there is more than a little interest in changing its use, for it appears the property and development interests are central in this. This is, however, unlikely to happen, as it is one of the most highly protected pieces of green space in the city, with more than a few historic associations.

What we have produced is a model of how we can articulate stakeholders and the sites they are interested in as two different sets of agents that interact within themselves as well as between. The model we have suggested is rather simple, but it does focus on what it might take to engender important changes in how these kinds of problems might be resolved. Of course, the problem can be formalized mathematically, and although the algebra is not difficult, it is needed so that one can work out weights and averages. The real power of this approach, however, is in dealing with big problems where it is not obvious how powerful interests might be or how important sites might be. If we have hundreds of stakeholders and hundreds of sites linked spatially, the sort of networks that might apply can be extremely tricky to explore. Moreover, in such problems, consensus is often difficult to achieve without ensuring that certain communication channels are put in place. This, then, is the process of geodesign.

Our argument here is that it is important in advancing this science that links GIS and design to build models not only of the subject matter and focus of the design but of the design process itself: models not only of the product but also of the process.

Most of the software that is being developed for geodesign lies more in the geo component of GIS than in the design component. But the process we are suggesting as good geodesign practices is a kind of map algebra, and it could be implemented as a way of combining land coverages within software, such as ArcGIS using the ModelBuilder toolkit. If we think of stakeholder maps as different land coverages, then the process of combination is similar to many overlay map techniques central to land suitability analysis. I am not suggesting that we should use GIS in this way, although it would be easy to add this into such generic software. But I think that formal models of the geodesign process are useful as thought experiments about how one should go about design, and they clearly suggest ways in which stakeholders with very different interests might come to some sort of agreed answer.

Note: A version of this paper was presented at the 2013 [Esri Geodesign Summit](#), held January 24–25, 2013. A PDF of the presentation is available at www.spatialcomplexity.info/archives/1109.

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GIS and The City 2.0

By Jack Dangermond

Seven billion. That number has received a lot of attention recently as the global population has grown past this mark. But lost in the media coverage of this milestone was another, perhaps even more fascinating, global statistic: more than 50 percent of those 7 billion people now live in cities, a number projected to grow to more than 75 percent during this century. In fact, there will be at least 19 cities in the world with a population greater than 20 million people by the end of the 21st century. Cities are human destiny.

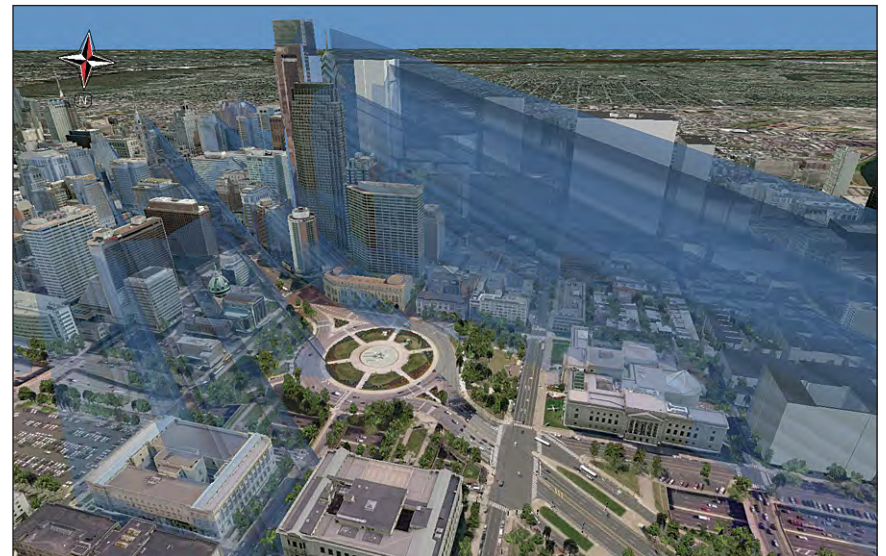
This growing recognition of cities as the center of the human world was further highlighted when The City 2.0 was awarded the 2012 TED Prize. "For the first time in the history of the prize, it is being awarded not to an individual but to an idea," the Technology/Entertainment/Design (TED) committee stated. "It is an idea upon which our planet's future depends."

Clearly, cities will play an increasingly important role in our survival. Cities offer easier access to services, and urban dwellers are more efficient consumers of limited resources. But as our cities become more populated and more numerous, how do we best manage this complexity?

We need to start thinking about cities in a different way.

Reimagining the Canvas

Fundamental to changing the way we think about cities is a reimagining of the way we abstract them. Maps are abstractions of geography and have proved to be particularly useful throughout our history. But traditional maps have limited our ability to manage and design in a holistic, comprehensive manner.



Tall structures can have a huge shadow impact on a city, as modeled here in CityEngine.

GIS technology has given us a powerful new context for extending our traditional methods of abstracting geography—a new canvas that includes everything that lies below, on, above, and around the city, including what exists inside and outside buildings, as well as how things connect to the city and how all these things change through time.

Cities as Ecosystems

Cities are the places where most of us now spend the vast majority of our lives. They have in fact become man-made ecosystems—vast assemblages of interdependent living and nonliving components—the primary habitat for the human species.

The recognition of cities as a habitat for modern man is leading to new approaches to their management and design. GIS technology has long been used to map, study, analyze, and manage natural ecosystems. It only seems logical to manage, model, and design our new man-made ecosystem with the same tried-and-true tools used for traditional ecosystems.

Buildings as Microcities

As our cities are growing in size and complexity, so too are the buildings that compose much of the fabric of the city. In effect, many buildings and facilities are becoming small cities themselves, and they need to be designed and managed as such.

GIS tools, used successfully for many years in fields such as environmental analysis and landscape planning, also support a broad range of applications inside and outside buildings and facilities. In fact, GIS can be used throughout the life cycle of a facility—from siting, design, and construction through ongoing use, maintenance, and adaptation, ultimately through closing, repurposing, and reclamation.

An Engaged Citizenry

Smart cities of the future will be those where the citizenry is engaged in city design and evolution, where we fully leverage the collective intelligence of the masses and allow everyone to actively participate in shaping our communities. Today, social media and mobile citizen engagement applications are enhancing a variety of government-citizen interactions involving public information, requests for service, public reporting, citizens as sensors, unsolicited public comment, and even volunteerism.

Geospatial technologies have already proved to be effective tools in supporting citizen engagement. Intelligent web maps are acknowledged as a catalyst for solving key challenges in creating a dialog through informed citizens. As web- and cloud-based GIS continues to evolve and social media and mobile devices become more pervasive, governments will continue to deliver innovative forums through interactive information and participatory citizen applications.

Designing The City 2.0

Geography is constantly changing—from wind and water erosion, natural climate shifts, tectonic and volcanic activity, and the dominance and extinction of species and ecosystems. But recent changes to geography as a direct result of human activities are threatening the survival of many species, including our own. And while the actions causing these monumental changes are often deliberate, much of the change to geography has been an unintentional by-product of poor planning and unsustainable actions—change that I call *accidental geography*.



Jack Dangermond at TED2010 in Long Beach, California
(Credit: TED/James Duncan Davidson).

[In my talk at TED 2010](#), I introduced the idea of geodesign—a concept that enables architects, urban planners, and others, to harness the power of GIS to design with nature and geography in mind. Geodesign results in more open participation through visualization, better evaluation of proposed scenarios, and a deeper understanding of the implications of one design over another. Combining the strengths of data management and analysis with a strong design and automation component is fundamental to designing The City 2.0.

A New Direction

Cities are intricate collections of materials, infrastructure, machinery, and people, with countless spatial and temporal relationships and dependencies, and require progressively more sophisticated tools to help us design and manage them. They are complex systems where we humans spend an increasing amount of our lives.

"This idea is capable of inspiring millions of people around the world to contribute to one of the biggest challenges and opportunities humanity faces," the TED committee stated when announcing the award of the 2012 TED Prize. "The City 2.0 is not a sterile utopian dream but a real-world upgrade tapping into humanity's collective wisdom."

Our challenge is to design our man-made ecosystems to achieve the maximum benefit to society while minimizing short- and long-term impacts on the natural environment. As an integrative platform for management and analysis of all things spatial, I believe that GIS technology can help meet this challenge.

Cities are our new man-made ecosystems, and it's time we start to think about them, manage them, and design them as such.

(This article originally appeared in the Spring 2012 issue of *ArcNews*.)

Can Geodesign Help Us Adapt to Climate Change?

by Jack Dangermond

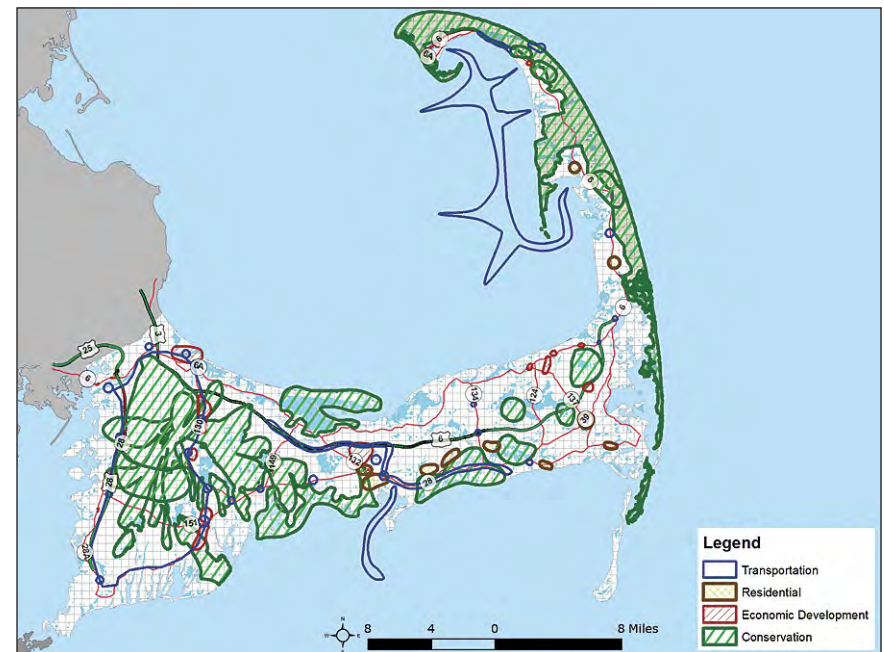
The earth's climate is changing, leading to serious problems for humanity in areas such as food security, health, and public safety. We need to adapt swiftly. But where do we start? Should we reinforce or rebuild existing structures? Or should we abandon existing settlements and relocate the population in some cases? And how can mass rebuilding/relocation efforts be best accomplished from human, environmental, and economic perspectives?

Geodesign is a framework for understanding the complex relationships between human-designed settlements and the changing environment, for quickly planning ways to adapt existing communities and build new ones in a more sustainable manner. This methodology helps us assess risk, identify change, create synergies, develop strategies, adapt to change, and monitor the results. Geodesign takes an interdisciplinary, synergistic approach to solving the critical problems of future design—to optimize location, orientation, and the features of projects at local and global scales.

How can geodesign help us adapt to climate change?

I recently asked this question at the Spatial Roundtable (www.spatialroundtable.com), where geospatial industry

thought leaders share their perspectives about concerns, trends, challenges, and technologies. Participants in the Spatial Roundtable offered thought-provoking insight into the role of geodesign in climate change adaptation, and I would like to share some important points made by several contributors.



This climate change scenario planning study for Cape Cod demonstrates the communicative power of geodesign using spatially informed models, fast feedback, and a large format sketching environment.

Designing Our Future

"Geodesign proposes to support decisions about the surface of the Earth through a combination of two sets of tools: one to allow designers to sketch proposals as they appear in map form, and the other to provide scientifically sound assessments of proposals through the execution of computer-based models," said [Dr. Michael Goodchild](#), Professor of Geography, University of California, Santa Barbara. "For example, a designer should be able to sketch a design for a development near a coastline, and to evaluate it based on scientific models of sea-level rise, as well as pollution of air and water, impacts on traffic congestion, and other environmental and social dimensions. By including projections of the effects of climate change, this approach offers a coherent and scientifically based way of addressing key decisions about development and land-use change."

A Global Dashboard

"If we really want to feed 9 billion people by the middle of this century, we need spatial data systems with real-time monitoring capacity and a data dissemination capability that can reach all stakeholders directly," said Dr. Wim Bastiaanssen, Co-Founder, eLEAF. "Without daily updates of intelligent, pixel-based data components, the great capacity of geodesign will not reach its full potential to support daily decisions in natural resources management—and become more climate resilient across the world. A data-enriched geodesign system supports authorities,

policy makers, water managers and individual farmers to make firm decisions. Geodesign principles fed with quantified crop, water, and climate data components must become one click away for everybody."

Scenario Development

"I am especially interested in the role geodesign might play in environmental scenario development," said [Dr. Elena Bennett](#), Assistant Professor, McGill University. "Scenarios, sets of stories about the future, can be a useful technique for thinking about a range of potential futures. In the environment, scenarios are often used to understand situations of uncontrollable or unpredictable futures, of which climate change is a classic example. Environmental scenarios can be qualitative or quantitative, and are often associated with images, but rarely with maps. I am interested in the potential for mapping scenarios, and for using geodesign as a way to bring together multiple disciplines to improve development and understanding of environmental scenarios in situations of climate change."

Integrating Knowledge

"Geodesign, by bringing multiple disciplines into a common geographic perspective, is the ideal integrator—helping societies identify those regions and policies where the interactions between climate stress and differing socioeconomic conditions are likely to make the most difference," said [Dr. James Baker](#),

Director, Global Carbon Measurement Program, William J. Clinton Foundation. "The resultant visualization and modeling will give guidance on the most efficient and effective ways to adapt both in the short and the long term. The long-term impact of climate change looms large—the sooner we can begin to adapt with tools like geodesign, the more resilient our societies will be in the future."

The Issue of Scale

"GIS, as a spatially based technology, offers a powerful approach to both the sketch and assessment aspects of geodesign, allowing decisions and their impacts to be investigated at a full range of scales from the very local to the global," said Goodchild. Dave Williamson, Founding Partner, Cascade Environmental Resource Group, agreed that scalability is a key issue: "Climate change is a global issue, and the models tend to operate at a global scale. However, planning decisions must consider meso-scale influences, while implementation generally takes place at a regional or local scale."

A Responsive Framework

"GeoDesign should strive to provide a systematic and consistently applied methodology for assessing risk and potential outcomes," added Williamson. "The current state of the science of climate change is such that new information is coming to light on a regular basis and yesterday's accepted fact is tomorrow's fallacy.

Geodesign should provide a dynamically responsive framework that can accommodate the ongoing shifts in the climate change model. When it comes to planning in response to climate change, the future will belong to the speedy and the integrated."

Moving Forward

"The geodesign framework is to be welcomed as another powerful arrow in the quiver of approaches and tools that will help us to plan and implement climate-smart development measures," said Gernot Brodnig, Geographer, World Bank.

"The time for implementation of strategic and tactical projects based upon this understanding is now," added Dr. Nguyen Huu Ninh, Nobel Prize winner and Chairman of CERED. "Making wise decisions to accommodate emerging changes will have major positive impacts on the health, security, and prosperity of populations in high risk areas around the globe."

I'd like to thank all of the Spatial Roundtable participants for their valuable insights on this important topic. You can read the complete responses [here](#).

About Jack Dangermond

[Jack Dangermond](#) founded Esri with a vision that computer-based mapping and analysis could make significant contributions in the areas of geographic planning and environmental science. The recipient of 10 honorary doctorate degrees, he has served on advisory committees for the National Aeronautics and Space Administration, the Environmental Protection Agency, the National Academy of Sciences, and the National Science Foundation.



(This article originally appeared on [April 23, 2012](#), in the *Esri Insider* blog)

Creating the World of Tomorrow

Written by Shannon McElvaney

Jennifer Sheldon is an ecologist, writer, and program manager specializing in terrestrial ecology and wild dog ecology. Her research emphasis includes development of spatial models of carnivore competitive interactions, as well as the demography of coyotes during gray wolf restoration in Yellowstone National Park. Her expertise includes working with multi-disciplinary and stakeholder teams on research efforts. She is the co-founder of [Yellowstone Ecological Research Center](#), and was vice-president for 16 years. She is currently taking a sabbatical year in Victoria, British Columbia working on a book about ecological systems, the human dimension, and resilience. Jennifer spoke at the



2013 [Geodesign Summit](#) which Esri recently hosted in Redlands, California. This interview was conducted by Shannon McElvaney after the event, with impressions of the event and about the future of geodesign.

McElvaney: This was the fourth Geodesign Summit Esri has hosted, but the first you've attended. What did you think?

Sheldon: The gathered group was unusually varied and included academics, industry leaders, urban planners, students, geographers, educators, and analysts. Carl Steinitz provided the unifying theme with his elegant articulation of the theory of geodesign.

Concepts flew, turned on a dime, and looped back into applications. Talks were met with rowdy applause then contemplative silence. We ate lunch in the midst of a barrage of creative interchanges—young students talked a mile-a-minute with industry leaders, National Park Service landscape architects, and city planners, all exchanging ideas in a congenial atmosphere. Themes included water, resources, restoration, urban landscapes, and the human element. The mix of GIS platform advances with applications and theory was catalytic and provided serious brain-food for all attendees, moving everyone out of their comfort

zones and into dynamic interactions during breaks and over meals.

Throughout, the theme of the Geodesign Summit was the open exchange of ideas. Dynamic presentations alternated with close-focus workshops. And threading through this free-wheeling and good-natured summit, the common language was empowered by advances in software, visualization technologies, and processing capabilities. Jack Dangermond's ready engagement provided a unifying good humor.

McElvaney: What at the Summit really made you think?

Sheldon: In today's highly technical and specialized world, solutions come from teams. Collegial, thoughtfully assembled groups of experts and non-experts working across disciplines can translate the complex technical requirements of today's design and planning challenges into reality-based solutions. We saw the best of this fusion and teaming begin to coalesce at the 2013 Geodesign Summit. It's the free interchange of thoughts and plans that gives the future its legs. The best of creative problem-solving happens with committed teams of creative, solutions-oriented people. The Geodesign Summit's setting and agenda provided a framework for a success. Maps provide the common language.

McElvaney: This year, we intentionally brought in biologists to mix with urban and regional planning and design professionals to cross pollinate. Did it work?

Sheldon: Ecologists provide insight into the physical mechanisms underlying good design choices (examples: hydrological models let us know about impermeable surface and greenspace planning for cityscapes; Ground truthing provides feedback on CityEngine flythroughs; Biodiversity assessments provide feedback on whether land set-asides are working effectively). In today's specialized world, talking with people from different disciplines is critical for solutions-oriented activities. Ecologists tend to be academic or management-oriented. It's good to build conversations with both of these approaches. From my



The Yellowstone Ecological Research Center has pioneered work by examining whole landscapes for extended timeframes, and by collaborating in multi-disciplinary teams.

(Photo by Hamilton Greenwood.)

perspective it was fruitful and productive. I learned a lot more about how urban planners approach their constraint space. More cross-discipline feedback from ecologists will be productive here.

One future activity might be to have a round-table to focus more tightly on solutions (e.g. integration of an eco-constraints layer into urban planning efforts). Begin with a real-world problem presentation, then focus a panel discussion on expertise from different fields and how the solution can be parameterized (and supported by software). Be specific about the software architecture needed. For example, how do we address unmet needs in ecological constraint layers in the built environment?

McElvaney: What do you think is needed to bring about the geodesign tools we will need for holistic planning?

Sheldon: We need a three-way interface of:

- Esri spatial visualization
- Ecological data and models
- [Remote sensing data](#)

Integration of these three entities is the *research and applications frontier* for impacts assessments. The biggest unmet need in impacts assessments is a standardized set of utilities across these three domains. Typically each project comes up with its own unique and unstandardized solution for data integration. While we wait for the incentive system in real world situations to be

adjusted, we can still provide the utilities to make impacts more realistic and accountable. [EAGLES](#) was a first cut of articulating the unmet needs of practitioners in this three-way integration. Ecology is ready for the next generation.

McElvaney: What did you think of Bran Ferren's call for a "Bill of Rights for the planet"?

Sheldon: All world-changing movements begin with a timely, self-evident idea carried by people who are bold enough to move it forward.

What we are really mulling over is 'Where do human interests and ecosystem interests intersect?' With Sandy, ocean issues, species declines, water quality, we intuitively understand that there isn't an 'us (humans)' vs. 'them (ecosystems)' frame any more. We are all supported within an integrated system of air, water, vegetation, ocean, and climate. This unified envelope can be mapped, measured, and supported through excellence in integrated design. Forecast models can yield a visualization of future outcomes for discussion and rational planning. One way to make it more tractable is to borrow from the legal disciplines and move toward the concept of 'standing' for systems and their components.

Obama's Climate initiative provides a first lever. The link between human health and ecosystem health provides a second lever. The costs of continued impacts of current practices provide the third argument: food security (soils and agricultural productivity);

energy issues; urban integrity; water issues all combine to make powerful economic arguments for eco-integrity.

As we move beyond simple arguments based on philosophy into a clear understanding of the linkages between ecosystem integrity and human well-being, a new evidence-based thought system will be essential. Spatial data represented clearly and accurately plays the keystone role.



Possible geodesign Hippocratic oath? Above all, do no harm.

(Photo courtesy of Jennifer Sheldon.)

McElvaney: One of the things that always comes up is the definition of geodesign, and we frequently go through a number of different definitions provided by various thought leaders. In simple terms, how would you explain the concept of geodesign?

Sheldon: The world of tomorrow is written in the (geo)designs of today.

About Shannon McElvaney

Shannon McElvaney is the sustainable development industry manager at Esri and a geodesign evangelist working on developing geodesign tools, techniques, and processes that will enable people to design, build, and maintain livable, sustainable, healthy communities. He has more than 18 years of experience applying a broad range of geospatial technologies across a variety of industries.



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Understanding our world.

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Governments, industry leaders, academics, and nongovernmental organizations trust us to connect them with the analytic knowledge they need to make the critical decisions that shape the planet. For more than 40 years, Esri has cultivated collaborative relationships with partners who share our commitment to solving earth's most pressing challenges with geographic expertise and rational resolve. Today, we believe that geography is at the heart of a more resilient and sustainable future. Creating responsible products and solutions drives our passion for improving quality of life everywhere.

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