



Understanding Earth

GIS Technology Drives a New Relationship
Between Humans and the Environment

Jack Dangermond and Matt Artz





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Mapping Redefined

In a word, geography is a science—a thing not of mere names but of argument and reason, of cause and effect.

—William Hughes, 1863

From the dawn of humankind, man has sketched crude abstractions of geography on cave walls and rocks. These early maps documented and communicated important geographic knowledge our ancestors needed to survive:

- What is the best way to get from here to there?

Early man used cave walls and rocks as a canvas to communicate and share geographic knowledge.

- Where is the water at this time of year?

technology to the serious environmental and geographic

- Where is the best place to hunt animals?

problems we were facing. And so the geographic information Our ancestors faced critical choices that determined their survival system (GIS) was born.

or demise, and they used geographic information stored in map The era of computational geography was led by the form to help them make better decisions.

groundbreaking work of Dr. Roger Tomlinson, who developed Fast-forward to the 1960s. The world had become significantly the Canada Geographic Information System in 1967. Similar more complex than it was for our early ancestors, and computers efforts took place at Harvard's Laboratory of Computer Graphics had arrived on the scene to help us solve increasingly complex and Spatial Analysis in the 1960s and beyond. Computational problems. The 1960s were the dawn of environmental awareness, geography forever changed the way we view geography and and it seemed a natural fit to apply powerful new computing place.

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Mapping Redefined



GIS is the technology of our times and is uniquely suited to assist in solving the problems that we face.

—Roger Tomlinson

A Context for Understanding

Geographic knowledge is information describing the natural and human environment on the earth. For our ancestors, geographic knowledge was crucial for survival. For our own survival today, geographic knowledge plays an equally important role. The biggest differences between then and now are that our problems are much more complex, and the sheer volume of data at our disposal is daunting. And whereas communicating geographic knowledge in the past was limited to simple maps, GIS

technology now enables a collective geographic intelligence that knows no spatial or temporal bounds.

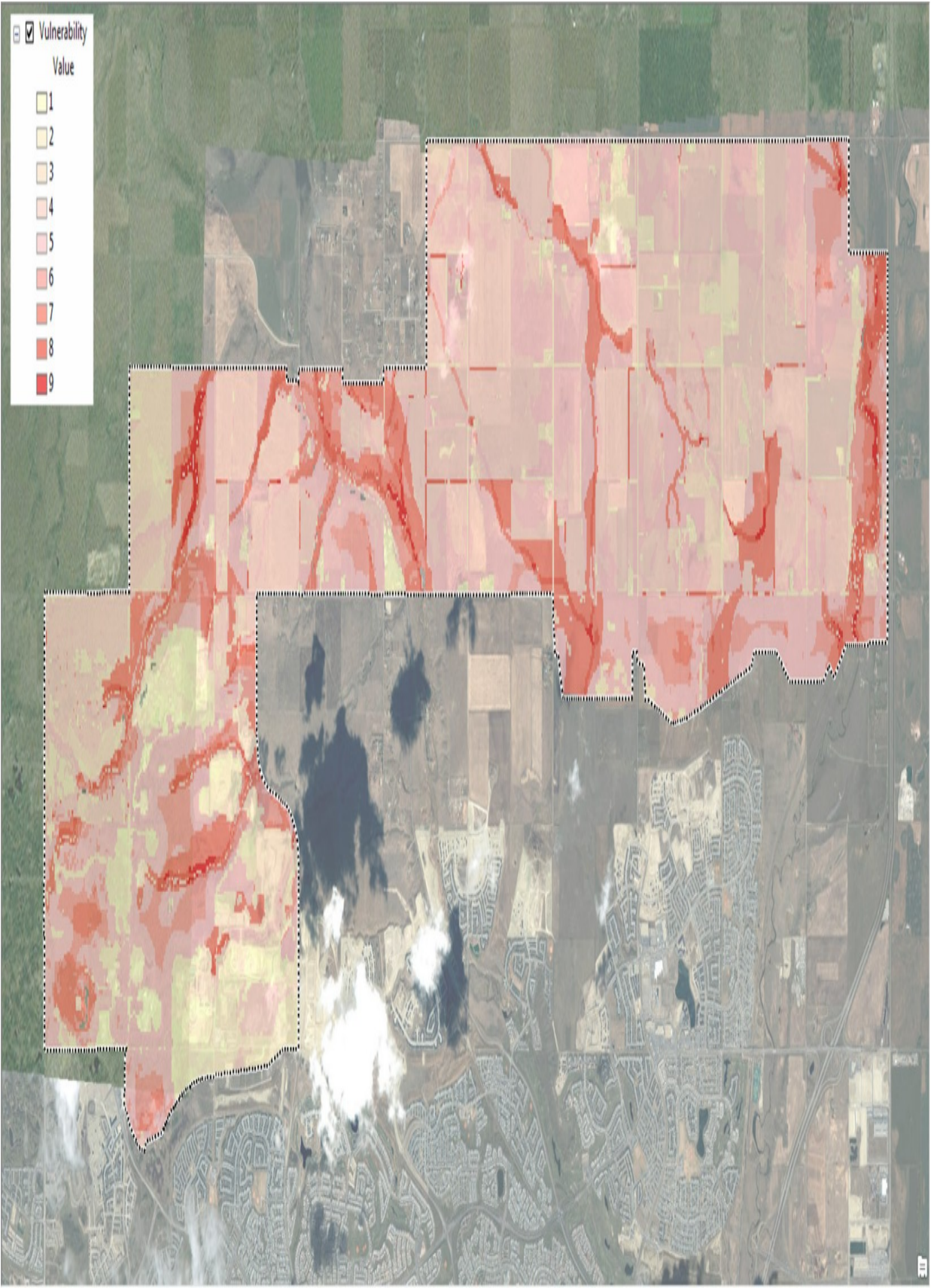
Dr. Roger Tomlinson pioneered the development of GIS, ushering in the Today we have more geographic data available than ever before.

era of computational geography.

Satellite imagery is commonplace. Scientists are producing Today, GIS has evolved into a crucial tool for science-based mountains of modeled data. And an ever-increasing stream of problem solving and decision making. GIS uses the power of data from social media, crowdsourcing, and the sensor web is information technology to examine geographic knowledge in threatening to overwhelm us. Gathering all this information—this ways that would be extremely time-consuming and expensive geographic knowledge—and synthesizing it so that we can more if done manually. The map metaphor remains the dominant easily understand it and act on it is the domain of GIS. More data medium for sharing our collective geographic intelligence, and does not necessarily equate to more understanding, but GIS is widespread use of GIS technology is creating a revolution in how already helping us to make sense of it all, turning this avalanche we understand our world and plan for the future.

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Mapping Redefined



of raw data into actionable information—a new context for some cases literally moving mountains, but also profoundly understanding our world and planning for the future.

reshaped its ecology.

Only when people know will they care.

And it's not just landscape-scale geographies that can be *Only when they care will they act.*

considered human-made ecosystems. In modern society, cities *Only when they act can the world change.*

and towns are where we spend the vast majority of our waking and sleeping hours. Even our homes and office buildings are

—*Dr. Jane Goodall*

themselves man-made ecosystems—vast assemblages of interdependent living and nonliving components. Entirely manA Framework for Action

made ecosystems have become the primary habitat for the Our traditional understanding of ecosystems as natural human species, and this is changing the way we think about, landscapes is changing. Anthropogenic factors are now the col ect, store, and use information describing our environment.

dominant contributor to changing ecosystems. Human beings A key aspect of our social evolution is recognizing the effects we have not only reshaped the physical aspects of the planet, in have already had on ecosystems, as well as learning to predict what future impacts will result from our actions. Once we achieve this level of understanding, we can direct our actions in a more responsible manner. This type of long-term thinking and planning is one of the things that make us human.

Recognition of the overwhelming dominance of man-made ecosystems also makes us cognizant of the tremendous responsibility we have—the responsibility to understand, manage, and steward these ecosystems with decisions based on sound science.

Understanding precedes action.

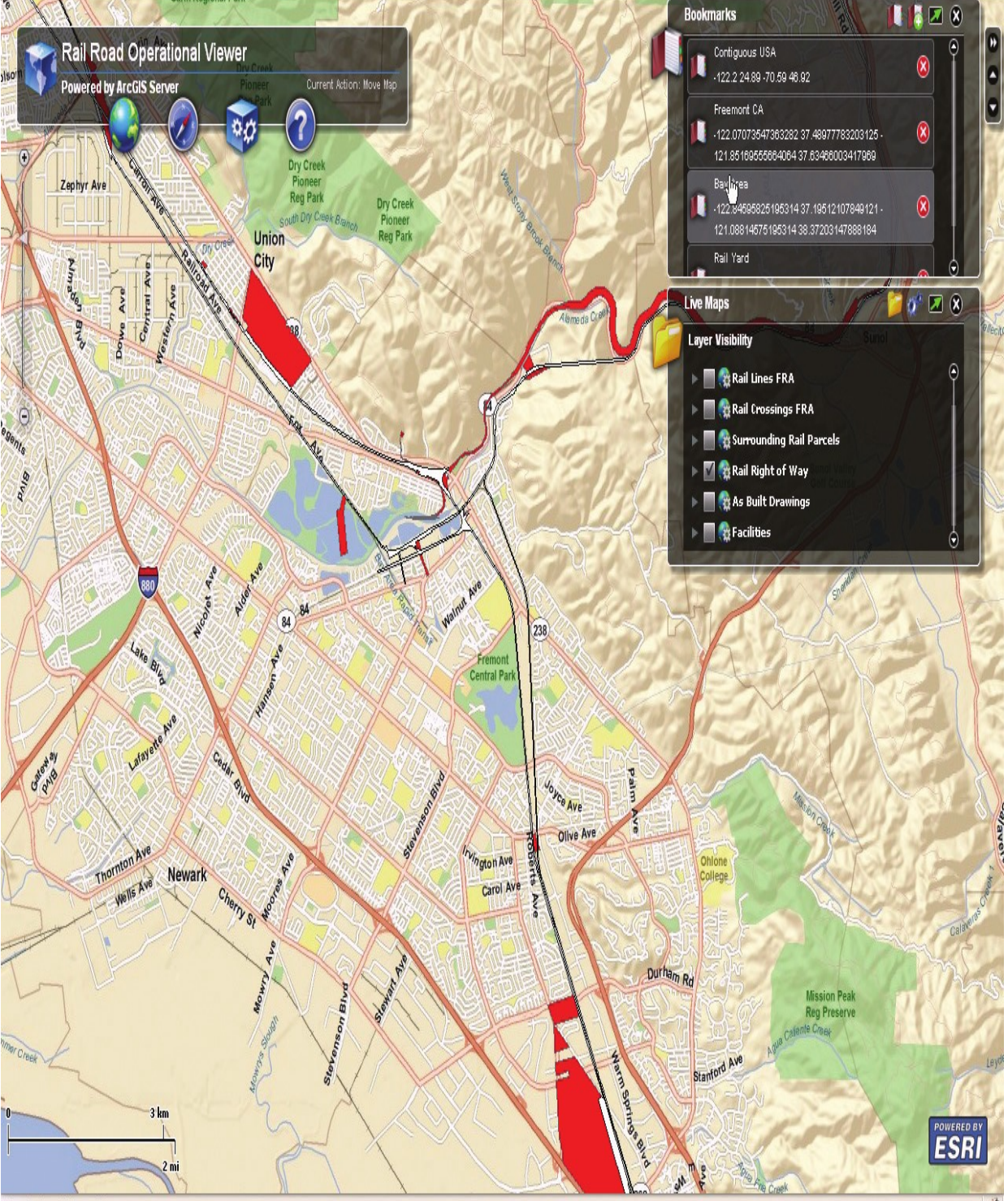
GIS helps us understand the vulnerability of the environment to our actions.

—*Richard Saul Wurman*

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Our Geospatial Infrastructure

The next 10 years will see an explosion of faster, more powerful People intuitively understand maps, and maps have historically mobile devices, and the line dividing cell phones and personal been our best method for communicating geographic knowledge.

computers will fade. Mobile devices will continue to grow to But over the last 10 years, we have seen a fundamental change support more geospatial functionality, and they will easily in the way geographic knowledge is delivered and used. Thanks connect to GIS-enabled systems around the world, empowering in large part to the Internet, our definition of what constitutes people to use and also create geographic knowledge.

a "map" is evolving quickly, along with geospatial information Democratization of data—both its widespread use and its management technologies, including GIS.

universal creation—will result in a new kind of infrastructure: a geospatial infrastructure. Over time, society will become increasingly dependent on this geospatial infrastructure, much as it has become dependent on other, more traditional forms of infrastructure such as electrical grids or highway networks.

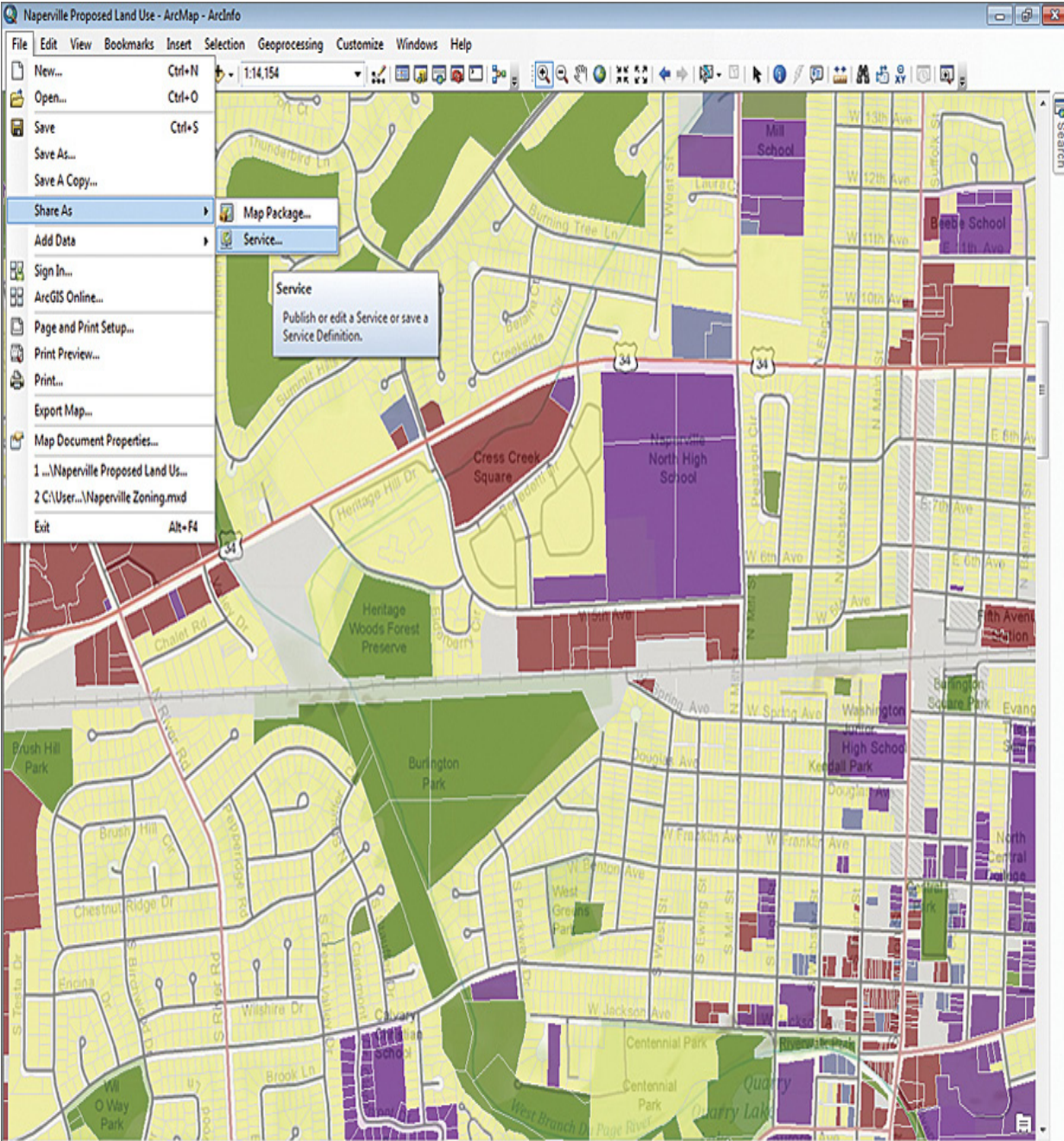
Our geospatial infrastructure includes details about physical infrastructure and other aspects of our natural and human-made geography.

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Mapping Redefined

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Map  **Evaluate**  **Act**



A New Approach

A transformation is taking place. Businesses and governments, A geographic information system lets us visualize, question, schools and hospitals, nonprofit organizations, and private analyze, interpret, and understand data in new ways. Its analytic citizens are taking

advantage of it. All around the world, people power can reveal relationships, patterns, and trends.

are working more efficiently because of it. Information that was With GIS we are not simply replacing paper-and-ink maps with limited to spreadsheets and databases is being unleashed in a maps on computer screens; we are evolving and extending the new, exciting way—through the use of geography.

definition of what maps are and redefining how we use and interact with them.

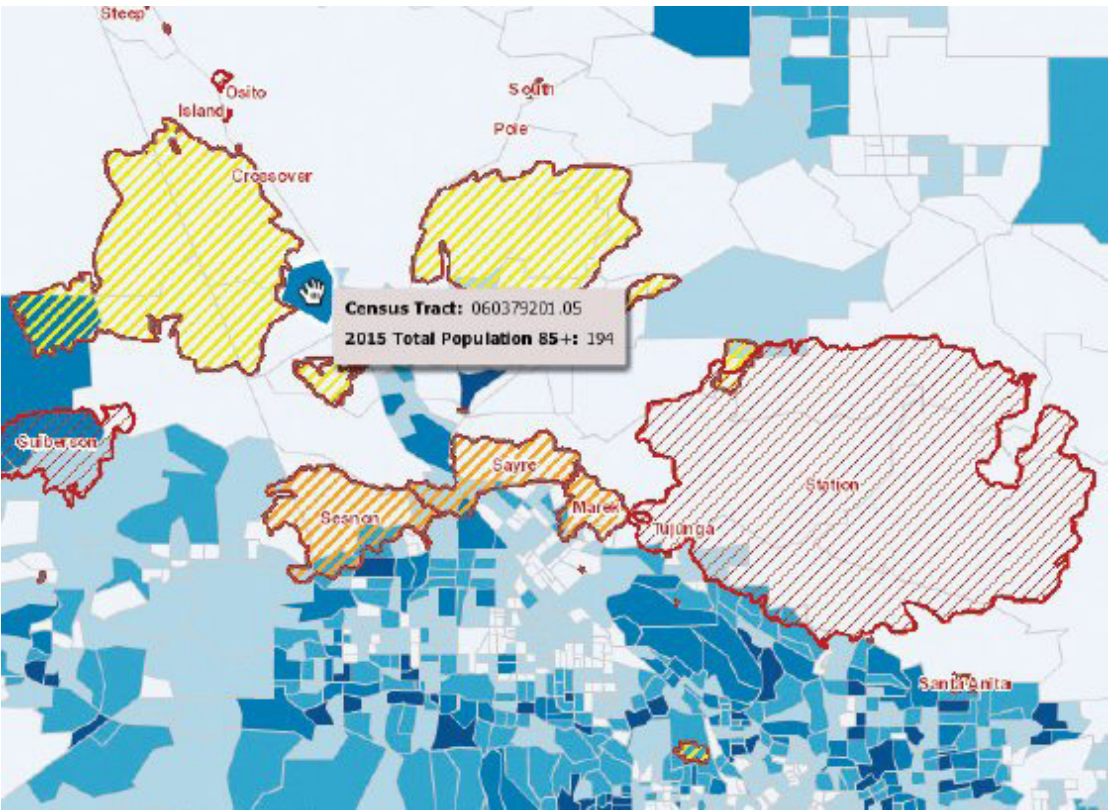
The Geographic Approach

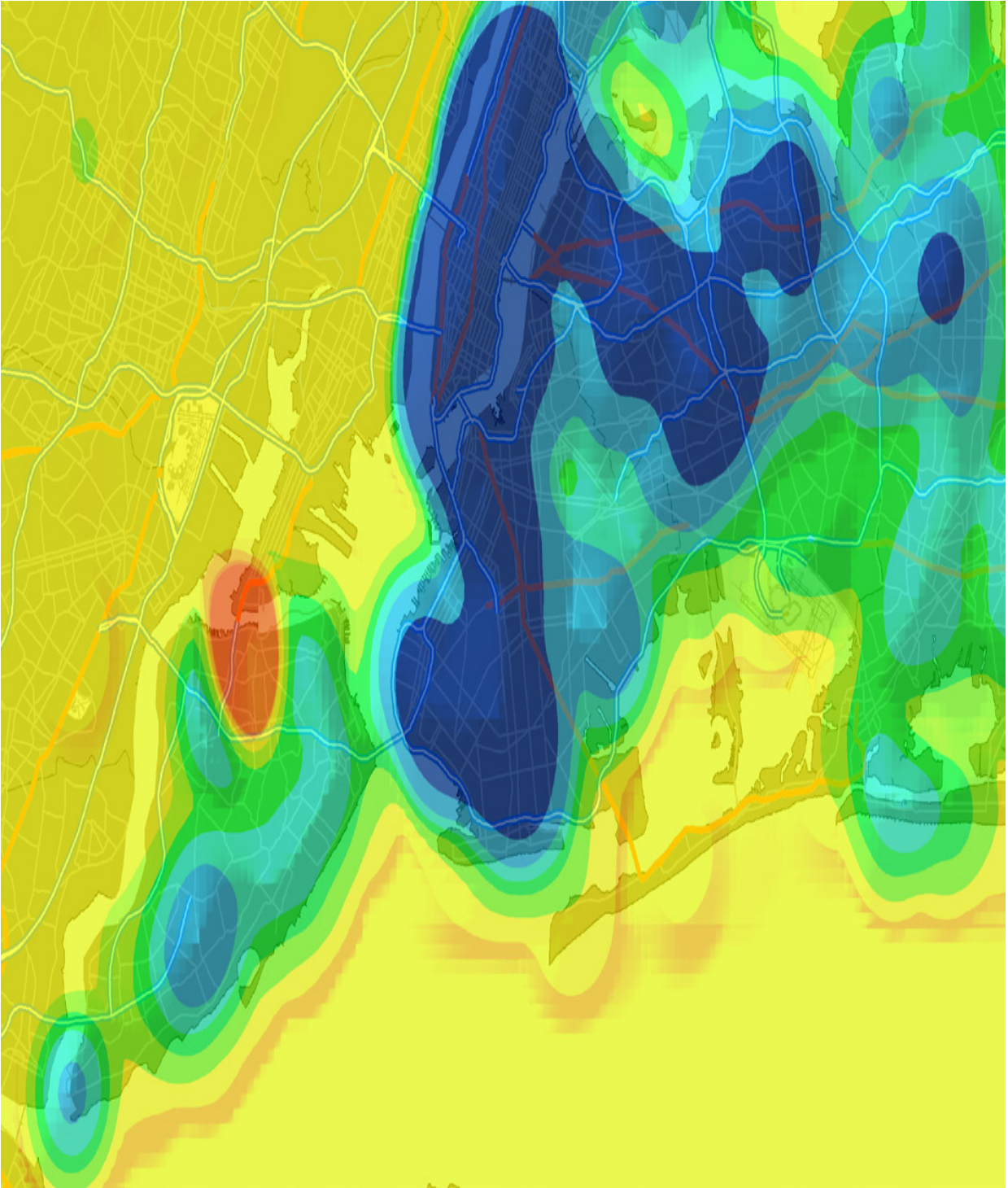
Maps are a proven method of communicating geographic knowledge. When a decision needs to be made, GIS helps us gather place-based information and organize it on a digital map. We then use GIS to evaluate the decision. Once we fully understand the geographic consequences of our decision, we can act in an informed, responsible manner.

GIS helps us see where things are and decide where they should be.

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A New Approach





This geographic approach to problem solving helps us answer a GIS benefits organizations of all sizes and in almost every industry, wide variety of important questions related to geography, such and there is a growing interest in and awareness of its economic as these:

and strategic value. The benefits of GIS generally fall into five basic categories:

- Where are my customers and potential customers?
- Cost savings resulting from greater efficiency
- Which areas of my town are most vulnerable to natural disasters?
- Better decision making
- Where should we locate a new elementary school?
- Improved communication

GIS helps answer such questions by combining data from

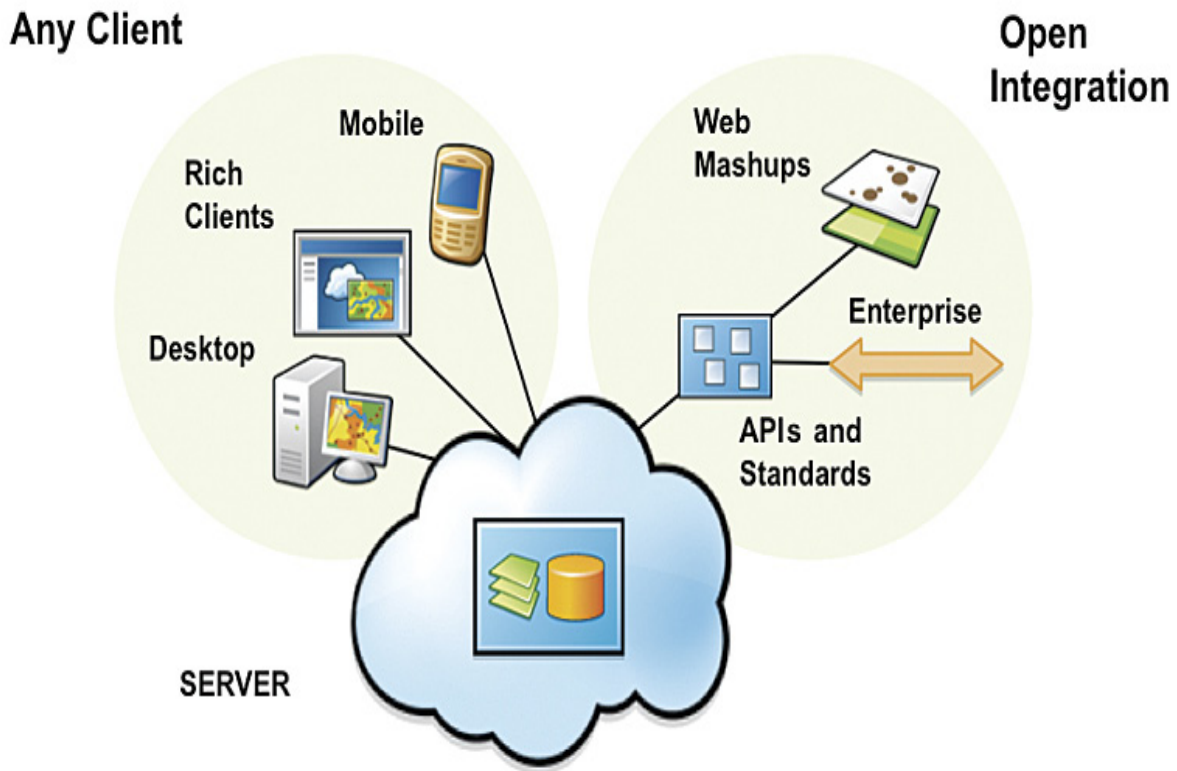
- Better geographic information record keeping governments and other sources in a personalized map.
- Managing geographically

GIS can produce "heat maps" to visually represent By comparing historical disaster data with vulnerable information using colors.

populations, GIS reveals patterns useful for disaster planning.

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A New Approach



Remote-sensing satellites and earthbound sensors are providing us with vast amounts of data about our planet. With the understanding of how the world is changing, GIS is changing the world.

The availability of new, easy-to-use GIS tools for displaying and analyzing this data, now everyone can be an explorer. GIS has a long history of successfully adapting to new technologies, applications, customer types, and business models.

The benefits to both society and the environment are far reaching and From mainframes to minicomputers, UNIX workstations to PCs, usher in a new era of understanding for our world.

From desktop to enterprise deployment, each round of technological innovation has led to improvements for GIS. Today, GIS continues becoming easier for anyone to use and benefit from GIS.

to evolve in response to changes in information technology.

The distributed computing environment enabled by the web introduces a whole new set of challenges and opportunities.

Merging with and adapting to the latest advances is making GIS

easier to use, more collaborative, more powerful, and ultimately more useful for the work you do every day.

The Cloud

Cloud computing delivers technological capabilities on demand as a service via the Internet. Unlike the classic computing model of operating system plus software applications with files and database storage, the cloud model consists of services, clients, hosted content, and virtual machines. In other words, you do not load and run software and store data on your computer; you

"The cloud" supports both enterprise and web deployments, transforming GIS access, usability, and collaboration.

log in and use the system in the cloud. In addition to allowing computing on the public Internet, the cloud can be implemented within a smaller, more secure community (creating a so-called

Evolving Technology

private cloud) using the same concepts.

The geospatial industry, the IT environment, and the world around us are all changing rapidly. We often talk about how GIS

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A New Approach



Cloud computing is emerging as an important technology trend. Crowdsourcing gives ordinary citizens the opportunity to provide in almost every industry, including the GIS community, and it is feedback directly to the government. It can significantly augment rapidly moving into the mainstream. For many people, this is a authoritative datasets. It provides extraordinary opportunities for more efficient solution for maintaining an information technology citizen science, and it can put a virtual army of volunteers on a infrastructure. It also provides a solution for many government large project in short order.

agencies, because it allows them to serve their data without the The challenge for GIS practitioners is to ensure the usability of cost of administering hardware.

this data in a GIS workflow or to turn this crowdsourced data into useful geographic knowledge. This can mean checking the data to make sure it is authoritative; it can also mean getting involved in data collection, structuring the process to ensure that the collected data has meaning and is appropriate and authoritative.

GIS tools supporting crowdsourcing are changing the way organizations collect and manage spatial data. New tools support the ability to modify geographic content within any web mapping application and allow online communities to become active contributors to geographic databases. Web editing makes it easy to capture ideas and observations for distributed problem solving. Crowdsourcing engages citizens in spatial data collection and civic solving and extends GIS editing capabilities to more people participation, empowering everyone to participate.

within an organization. These capabilities allow everyone—

from authoritative data editors to citizens on the street—to
Crowdsourcing

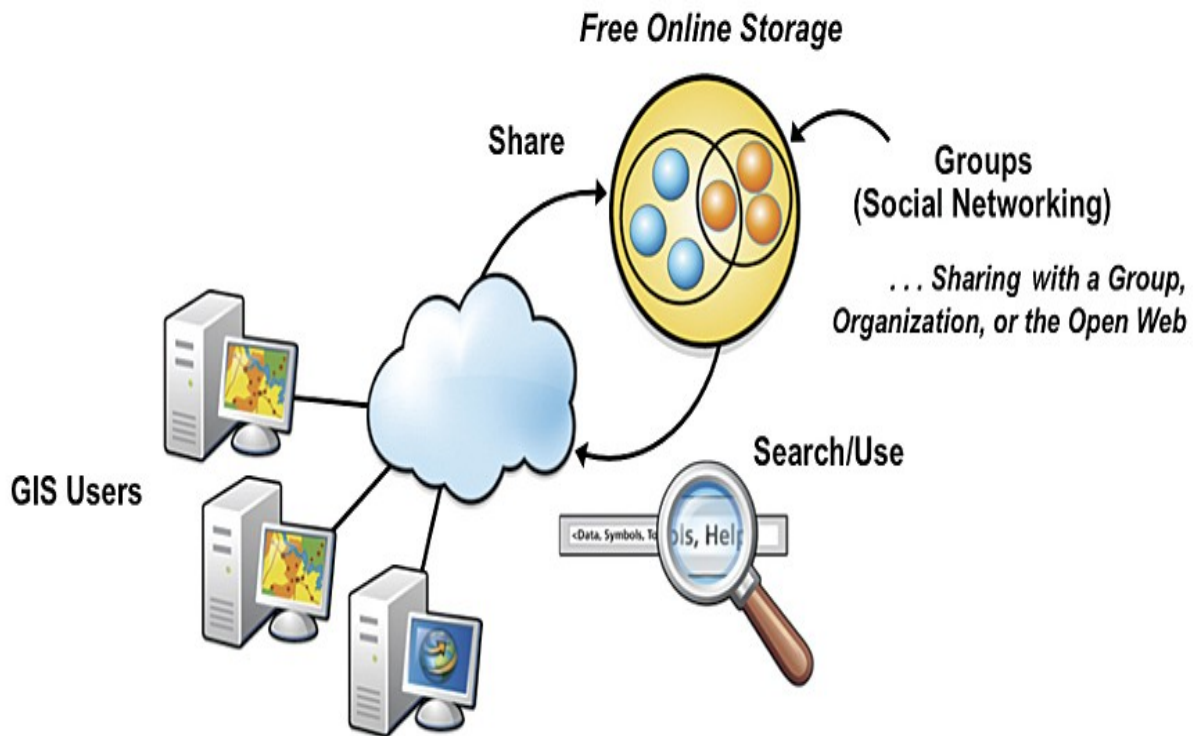
contribute content to the geodatabase. This will enrich geospatial infrastructure, giving GIS practitioners new types of data to use, (VGI) or user-generated content (UGC), crowdsourced data is managed, interpreted, and incorporated into their work.

data contributed by nonauthoritative sources (e.g., everyday citizens). Long the keepers of purely authoritative data, GIS

practitioners are beginning to take crowdsourced data seriously.

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A New Approach



Neogeography

With new GIS collaboration tools, people can share and discover. The neogeography movement—emphasizing ease of use, maps and apps and mash them up through virtually any device.

visualization, mashups, and so on—has been very successful. The map is still the focus, but this map is different: behind this at changing the way society uses and interacts with computer-map sits the data model; the symbology of the map; and, in based maps and geographic knowledge. Purveyors such as some cases, analytics. So when you share a map, you're not Google and Microsoft have made great advances in basic simply sharing a picture; you're sharing a collection of geographic mapping, visualization, and mashups, and in the process have knowledge. GIS professionals are already using this capability to shown us new user interface patterns. GIS technology is learning from these new patterns and incorporating them in the next generation of software. As a result, the distinction between the world of neogeography and the GIS world is gradually disappearing, and

GIS technology is becoming much more straightforward. This simplification comes from a new focus on how everyday people use the information and capabilities of GIS, resulting in a simple yet powerful system for working with maps and geographic knowledge. These changes are greatly increasing usability of the technology by GIS practitioners as well as society in general.

With GIS in the cloud, anyone can share maps, data, and applications.

Collaboration

New collaboration technologies are redefining how we work create knowledge, maps, and models and easily publish them on together and share geographic information at every scale. This the web for anybody to access

collaboration crosses traditional lines such as organizational boundaries, professional domains, and geographic borders.

No one organization can create the GeoWeb or own the entire Sharing gives people access to vast stores of geographic global spatial data infrastructure. These are being constructed knowledge that was previously difficult or impossible to obtain by thousands of individuals and organizations all over the world and leads to more informed decision making.

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using new collaboration tools to create geoservices and build applications on top of this infrastructure.

GIS Is Changing

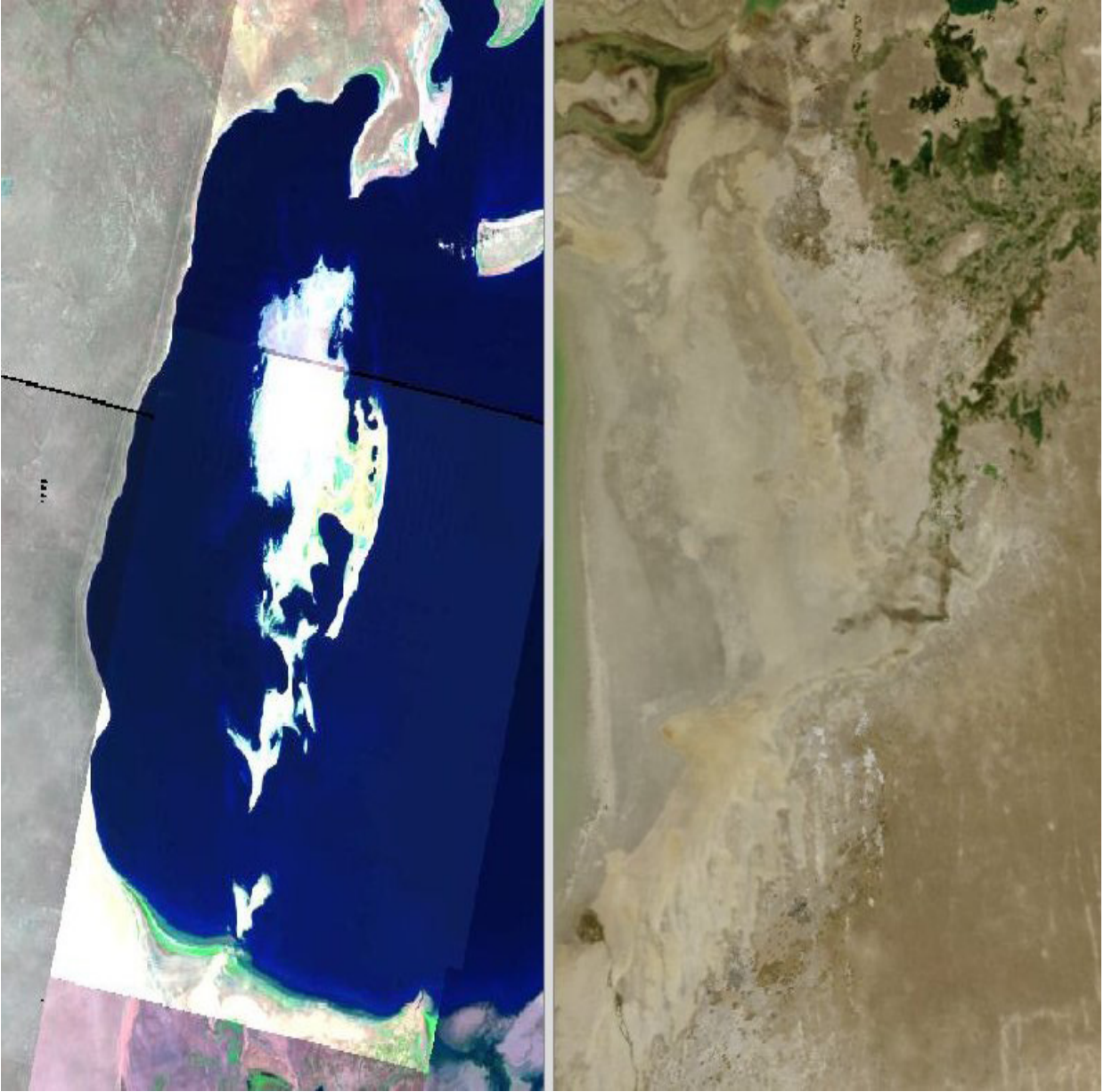
GIS has proved to be a flexible, adaptive technology, evolving as the information technology ecosystem around it changes. At each step in this evolution, GIS has not just adapted to these changes but embraced them, becoming more powerful and more valuable. Recent technological advances are helping us reenvision what a GIS is in a new context. As a web-hosted or cloud-based system with ready-to-use maps and apps, GIS is rapidly moving toward the vision of use anywhere, anytime, by anyone.

How we use GIS, the way we interact with it, and the way it interacts with the world are all changing. While some of this change has been and will be driven by new tools and technology, the biggest driver of change is you, the GIS user. Esri is not redefining GIS; you are. You're identifying the technologies that need to be embraced and the new functionality that needs to be added; and perhaps most significant, you are showing how GIS

can be applied in new and exciting ways for the betterment of humankind and the environment.

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A New Approach



A New Understanding

Stories play an important role in society, and storytelling is one of the things that make us uniquely human. Stories convey important knowledge about the world around us, often in a simplified yet dramatic fashion designed for maximum impact. We have much to learn, remember, and understand in life, but wrap a great story around something, and it will make an impression on us that lasts a lifetime.

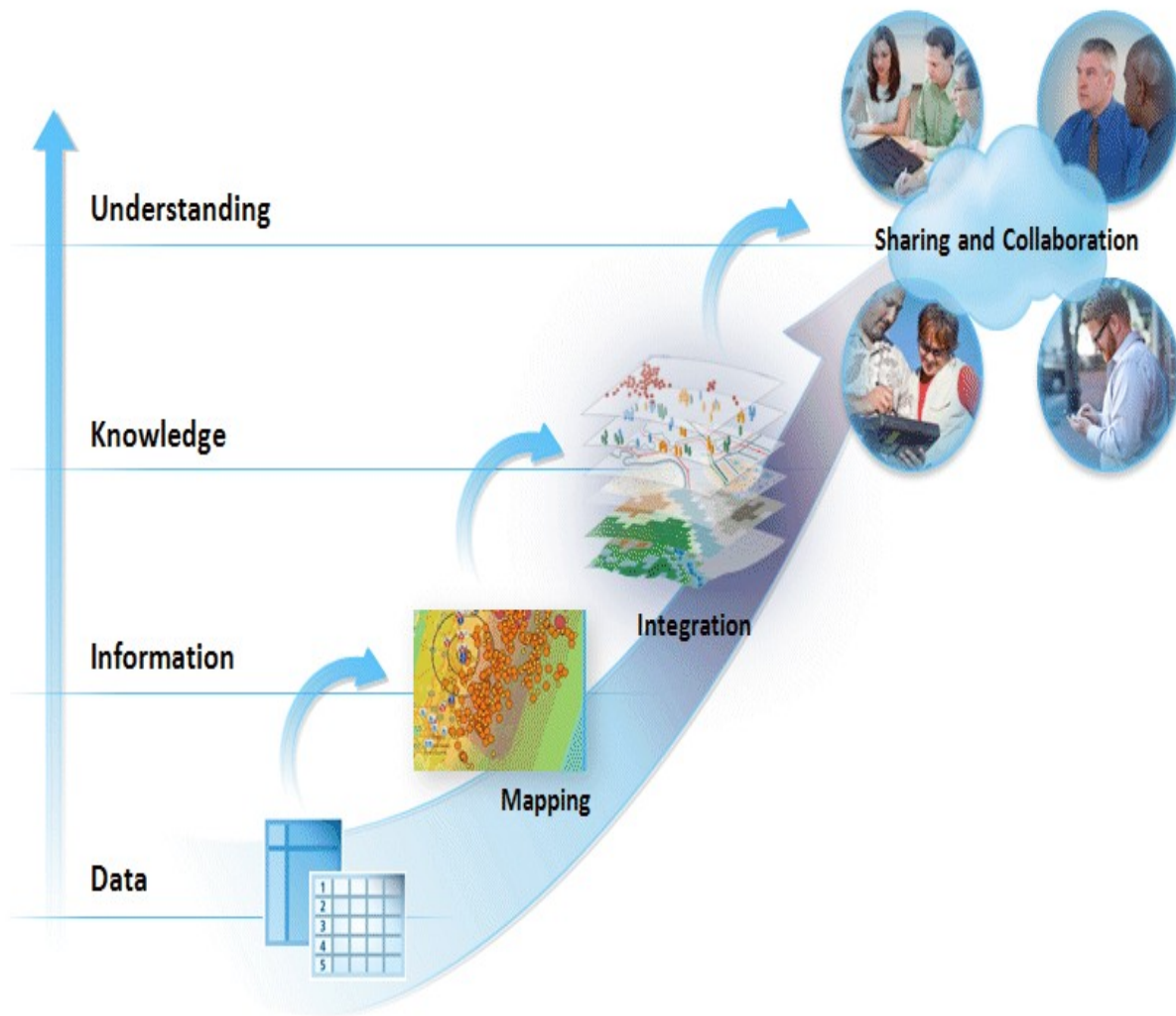
Maps are wonderful organizers of information, and they are an ideal stage on which to tell stories. But the stories that maps tell are not designed strictly for entertainment. Stories told with maps are designed to educate, inform, and inspire people. They are a platform for understanding and action.

What Is Understanding?

Our world is changing rapidly, and we're increasingly aware of the role humans are playing in that change. Climate change, GIS is an important tool for telling stories that help us understand how human activity is reshaping the surface of the earth.

urbanization, security, poverty, inequality—these are difficult problems that we must deal with, and they're affecting us approach. We need collective intelligence, and our actions need as individuals as well as impacting our organizations and to be based on this intelligence. An informed, science-based governments. For us to really address these things, we can't just approach is our best hope for confronting these unprecedented keep doing the same things that got us here. We need a different challenges. And the people who use GIS technology are playing Understanding Earth April 2012

A New Understanding



an increasingly important role in helping to create this new **GIS as a Language**

understanding of our world.

Geography has always been a critical type of information that Understanding is about knowing. It's quite human and is built on humans—in fact, all animals—collect, organize, and use. Place-real experiences, reasoning, and deep thinking. Knowing enables based information is vital to survival on our planet. As our world us to understand, think, predict, explain, add meaning, and has become

more complex, and our ability to understand has gain insight. Our minds are the framework within which all this also grown, GIS technology has evolved to help us process happens. They organize and synthesize information for us, then information about place and put it in a context that al ows us to integrate it into our lives. This is understanding.

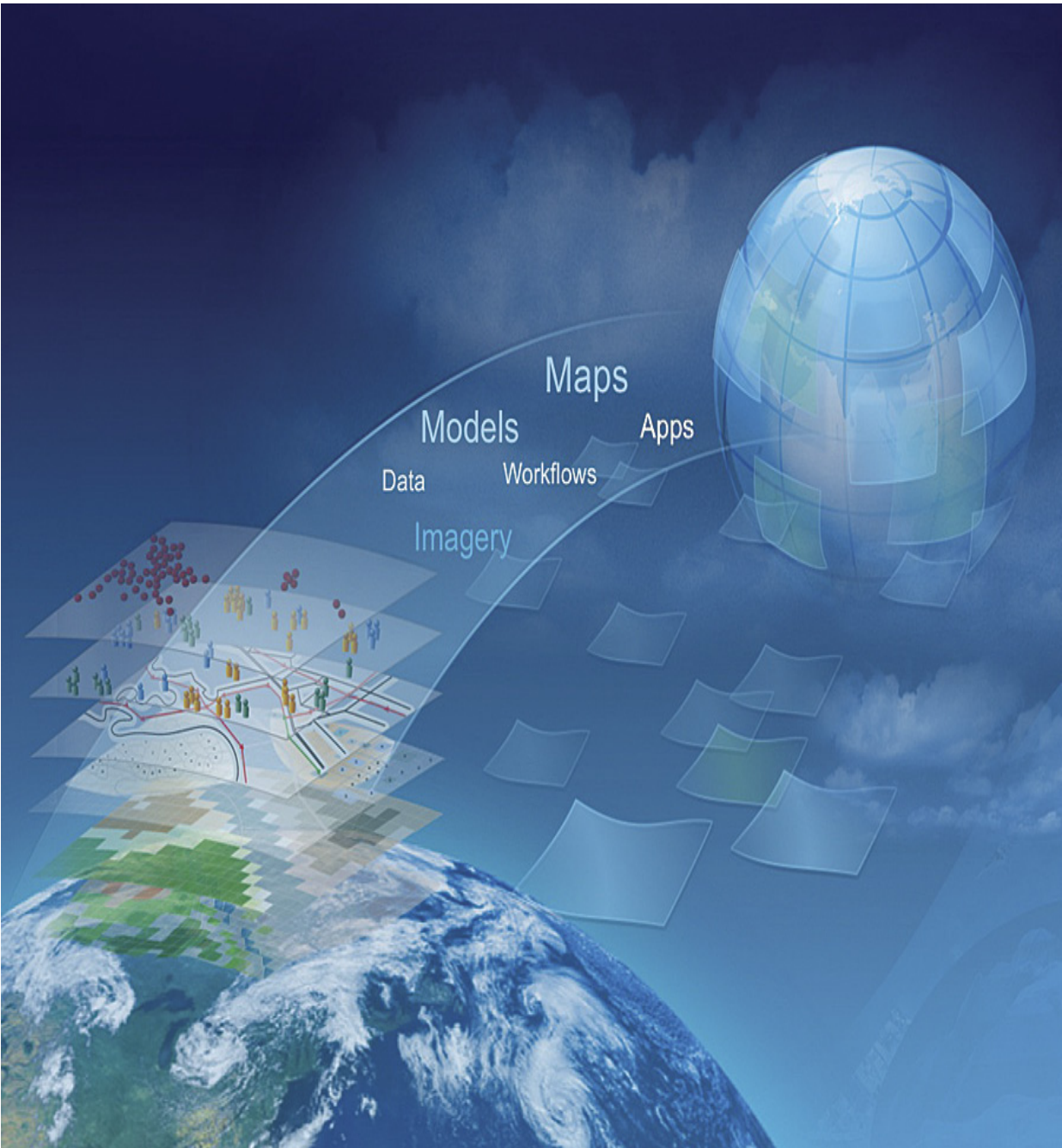
act. GIS is actually extending our minds by abstracting our world into pieces of knowledge that we create and maintain—data, imagery, models, maps, and apps. GIS is facilitating a systematic framework for knowing, and our shared work is leading to col ective understanding.

This is not just theoretical. From the beginning, GIS has been a very practical technology. When Tomlinson and his col eagues first began to implement these ideas in the 1960s, the problem was to harness the power of information technology to gain an understanding of geography that the human mind could not deduce without the assistance of computers.

Today, GIS integrates and synthesizes information from many sources and does it in volumes we could not have imagined 30 years ago. The availability of new technologies and the growing concern for our planet mean that we are producing GIS helps us to understand and to make better decisions.

an ever-increasing store of data describing our earth. We're being bombarded with data from a combination of old and new sources—satellites, sensors, crowdsourcing ("human sensors"), Understanding Earth April 2012

A New Understanding



With the number and severity of the problems facing our modern world, many of them having to do with place, GIS is becoming an essential new language for understanding.

Our species needs, and deserves, a citizenry with minds wide awake and a basic understanding of how the world works.

—*Carl Sagan*

GIS for Everyone

A new pattern for GIS has emerged, making GIS available to everyone. A long progression of efforts is bringing our work—

substantial, authoritative source information—to the web and blending it with social network and crowdsourced information.

This new pattern is making all of this work available through GIS extends our minds, abstracting our world and providing a systematic framework for understanding.

lightweight viewers and mobile devices, providing a broad context of understanding to individuals, organizations, and models, digitized historic records, and much more. Only when governments—to everyone.

these billions of bits of information are combined and organized But will this new pattern be broadly adopted? Is it just of interest can we achieve a higher meaning—a true understanding of to GIS professionals, or will it be adopted by a wider audience?

our world. And arriving at this understanding will require the right technology and culture for sharing our data and building a In fact, because the benefits are so great, this new pattern common geospatial infrastructure.

of GIS for everyone is already being broadly adopted. It is connecting GIS professionals with knowledge workers, As a kind of language, GIS also facilitates communication and managers, policy makers, and citizens, extending the reach of col aboration, breaking down barriers between individuals, geographic knowledge to everyone. It is empowering citizens organizations, institutions, and the world. This is part of its power.

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to participate in the same network environment, using the same infrastructure and sharing common services, to create a collective understanding.

GIS professionals continually amaze us with the creativity they display in applying the technology in solving complex problems and supporting critical decisions. From sea-level rise to deforestation; from disaster recovery to disease monitoring; from vehicle routing to demographic analysis, it's clear that GIS

is already being widely used as a tool to help us understand and act.

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Seeing the Big Picture

Geography has at least one thing in common with other

[Jerry Dobson](#), professor of geography at the University of Kansas, disciplines: it has become fragmented. As our world has become suggests that we already have the ideal tool for the job: the more complex, science has responded by becoming narrowly macroscope.

focused. Thousands of very smart people are making remarkable Citing the work of [Joël de Rosnay](#), an early proponent of systems discoveries in their own disciplines. But who is looking at the "big thinking, Dobson argues that the future of geography is "the picture"?

macroscope"—a framework for assembling large amounts of It's only logical. When life gets complicated, we often tend environmental and human knowledge so that we can get a truly to focus on the little

things. It's a coping mechanism. It helps geographic understanding of our world.

us deal with being overwhelmed; it helps us feel as if we are *We have in our hands a new scientific instrument as* accomplishing something.

powerful as any that have come before it, including At some point we need to take a step back and realize that we *the microscope and the telescope. Collectively,* can't understand an entire forest if we're addressing issues one *GIS, GPS, satellite remote sensing, and popular tree* at a time.

geographics constitute a macroscope that allows scientists, practitioners, and the public alike to view We've done an admirable job of examining and understanding a *the earth as never before.*

multitude of component pieces that make our planet work. Now our grand challenge is to integrate all this knowledge so we can GIS technology is the unifying force that can bring together understand the big picture.

fragmented data and disciplines into a common framework.

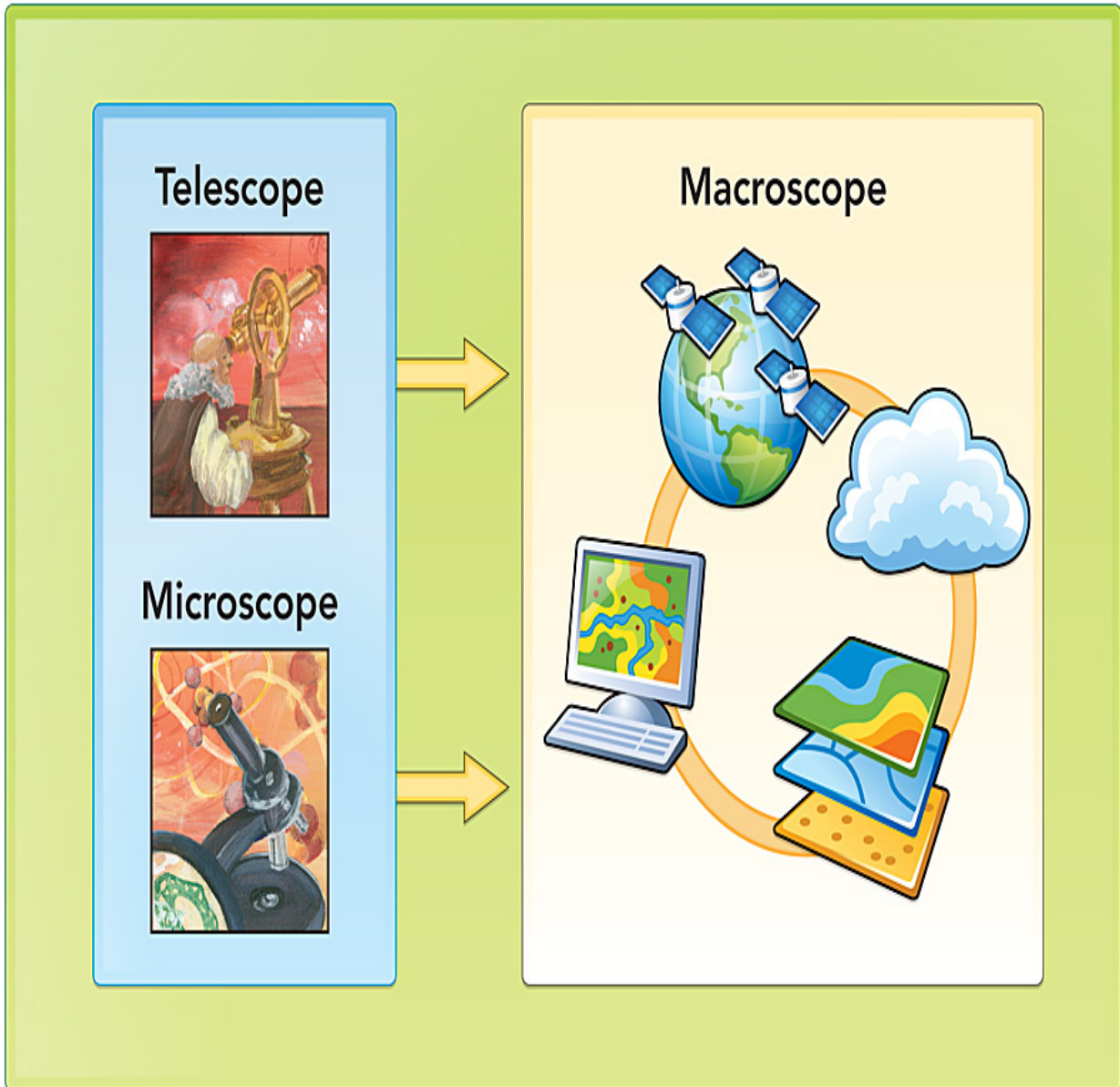
Collating and combining all the little discoveries is the next But how do we put all the pieces back together again so that scientific frontier. It's where the next big discoveries will be we can understand the whole? How do we defragment our made—by enticing people to view old questions in new ways—

geographic knowledge?

and dramatic new insights are likely to result from this.

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Seeing the Big Picture



by the microscope and telescope. Surely our professional lives will be richer, and science itself will gain, if we, who know the marvelous instrument best, insist on using it ourselves to tackle the greatest mysteries of our time.

The Geoscape

The world around us is a complex place, and one way we manage that complexity is through a process of abstraction. In its purest

sense, abstraction is about the reduction of detail down to the bare essentials we still need in order to understand.

Maps are a fascinating example of abstraction. Maps are abstractions of landscapes and geography, and they have

"This geographically enabled macroscope . . . allows humans to prove to be a particularly useful aspect of human technology visualize earth processes extending over vast regions or even the throughout our history. Until relatively recently, maps were whole globe while still maintaining the finest measurable detail,"

predominantly two-dimensional: paper maps with complex says Dobson.

geography abstracted onto a flat surface. New methods of *Clearly, there is much left to discover, and our presentation were created in an attempt to relay complex terrain community is in an ideal position to advance the* and other information that moved beyond the two dimensions, *macroscope and support or lead the coming* but these methods, while useful, often fell short of conveying the *revolution in science theory*, continues Dobson .

true nature of complex geographic space.

The macroscope is here today, and science is already Enter computers. The move from paper-based abstractions *changing in response to it. We are entering a new* toward computer-based abstractions of geographic space has *scientific era that may be every bit as exciting and* given us a powerful new context for understanding—and not just *enlightening as the revolutions prompted earlier* for two-dimensional landscapes, but for geography spanning the Understanding Earth April 2012

Seeing the Big Picture



third and fourth dimensions as well. Bill Miller likes to call this new canvas "the geoscape."

Beyond Landscape

Mil er, head of the GeoDesign Services group at Esri, has a vision for the integration of geospatial technologies with the design process—a vision long shared by a group of people that includes University of California, Santa Barbara's Michael Goodchild, Harvard University's Carl Steinitz, and a handful of others. Mil er took the first step toward

making this vision a reality when he assembled a small team to develop a tool that allowed users to The geoscape provides us with a new canvas for designing a better future.

quickly sketch features in a GIS environment—the first small step toward what is now commonly referred to as "geodesign."

is action, and before we can design, we must understand.

Geodesign—the act of thoughtfully creating the future for the While identifying the technology hurdles the GIS industry mutual benefit of humans and the natural environment—requires needed to overcome to fully realize the promise of geodesign, a heightened level of understanding.

Mil er noted a fundamental contextual obstacle: our traditional approach to abstracting the landscape severely limited our Understanding the world for the purpose of geodesign ability to move forward with geodesign. We couldn't fully realize necessitated extending our view of geographic space. "This the vision of geodesign without a framework for a more holistic, meant moving from 2D to 3D and to 4D, coupled with the idea comprehensive understanding of the world around us.

that most data, at some level, is spatial and that all types of spatial data (physical, biological, social, cultural, economic, urban, **A New Canvas**

etc.) can be georeferenced," states Mil er. "This ultimately led to an expanded view of what is typically envisioned, or imagined, Different levels of understanding often require different levels when referring to the geo portion of geodesign."

of abstraction, and it's clear that's what was happening with geodesign. As TED founder Richard Saul Wurman has so Extending our traditional methods of abstracting the landscape succinctly stated, "Understanding precedes action." Design to include 3D "provides us with the ability to georeference what Understanding Earth April 2012

Seeing the Big Picture

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lies below, on, and above the surface of the earth, including what geodesign, "ensuring that our designs consider everything that exists inside and outside buildings, as well as 4D geographic supports or inhibits life."

space, or how things change through time," Mil er notes. "This The concept of the geoscape gives us a framework for extending gives us the added ability to georeference time-dependent our thinking about and understanding of the world around us.

information such as population growth or the migration of a toxic As we move from thinking just about the surface of the earth plume through a building."

to now including what's below and above the surface, we take Mil er likes to define *geoscape* as the planet's "life zone,"

into consideration the full spectrum of the earth's life support including everything that lies below, on, and above the surface system. This represents a significant transformation in the way of the earth that supports life. The geoscape expands the view people think about geography, geodesign, and the application of of what constitutes the content of geography as well as the geospatial technologies.

dimensional extent of the geographic space used to reference
Designing a Better World

that content. It gives us the context we need to actually do The geoscape gives us a new canvas for understanding, for moving beyond traditional mapping for navigation and location, and for 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 al , as Mil er is fond of saying, "The purpose of design is to facilitate life."

The New Explorers

As the scientific foundation of GIS, geography has for many years been concerned with exploring and describing our world.

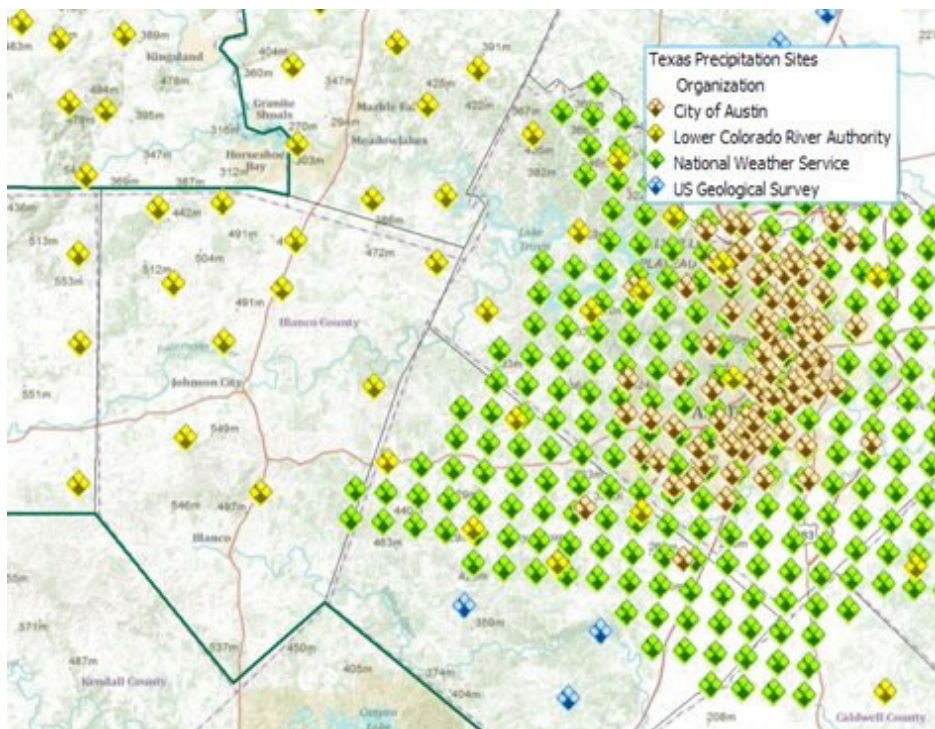
Historically, explorers led grand expeditions to the farthest reaches of the globe. This golden age of exploration contributed The geoscape extends our thinking and understanding of the world around us.

greatly to our understanding of how our world works.

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This was fol owed by the space age—an era where we completely the sheer volume of data being col ected, are spawning a new left the planet and turned our cameras and sensors to look back age of exploration. But the new explorers are navigating a vast, on our home, giving us an entirely new perspective of ourselves, uncharted

sea of data. What do we do with all of this sensed our planet, and the opportunities for exploration that await us.

data? How can we make sense of the sensor web?

No longer bound to the surface of the earth as our species had This new sensor web has inundated us with data that needs been for untold mil ennia, the view from a few hundred miles up to be stored, managed, analyzed, and used to inform better in space gave mankind its first glimpse of our planetary system as decisions about our many environmental chal enges. Integrating a whole.

and synthesizing all this disparate sensor data into a single, While data remotely sensed from satel ites continues to play an important role in monitoring and understanding our planet,

"earth observation" has more recently taken on a whole new dimension, thanks to the deployment of an increasingly more complex and pervasive network of earthbound sensors. These sensors are practically everywhere you look—and in places you could never imagine. From stream gauges to seismographs, from weather stations to air quality monitors, from ocean buoys to even ourselves, countless sensors are measuring and col ecting important data about our planet at a rate that was inconceivable just a short time ago.

Modern science and advanced technology have resulted in unprecedented access to global environmental information through the placement of countless sensors across the planet—

and the linking together of this information through the Internet.

GIS enables real-time integration of sensors from multiple We're col ecting more information about the geography of planet sources, using maps as a means to help us understand our world.

Earth today than ever before. New data sources, along with Understanding Earth April 2012

Seeing the Big Picture

comprehensive view—a global dashboard—is our next great opportunity for exploring our world.

A global dashboard is a decision support tool that helps monitor current conditions, identify change, and drive informed action.

It enables exploration at scales from local to global. It allows people to visualize large, complex spatial datasets in the context of their neighborhoods, their streets, and their houses. The ability to explore a world of data from a personal perspective is a very powerful idea.

Thanks to the rich information flow provided by our new world of sensors and the availability of new mapping tools to display and analyze this information in context, now everyone can be an explorer. This has far-reaching benefits to both society and the environment, ushering in a new era of science-based understanding and leading us toward more informed, equitable, and sustainable action.

The world, indeed the whole universe, is a beautiful, astonishing, wondrous place. There is always more to find out.

—Derek K. Miller

Understanding Earth April 2012

Seeing the Big Picture

Designing Our Future

Design is always and necessarily an art as well as a planning before it, geodesign takes an interdisciplinary, problem-solving activity.

synergistic approach to solving critical problems and optimizing location, orientation, and features of projects both local and

—*David Pye, The Nature of Design*

global in scale.

The key to developing a true understanding of our complex and Design is art within the framework of limitations—limitations dynamic earth is creating a framework that allows us to take many that arise as a result of function, world view, bias, and other different pieces of past and future data from a variety of sources factors, but also limitations that arise as a result of place. Design and merge them in a single system. GIS is a sophisticated considering place was at the core of Ian McHarg's beliefs, and it technology already in widespread use by planners, engineers, is the basis for research and development efforts in the emerging and scientists to display and analyze all forms of location-field of geodesign.

referenced data about the health, status, and history of our planet.

To a certain extent, this is already done today by numerous GIS practitioners in fields like urban and regional planning and GIS enables a [geodesign](#) framework for analyzing and managing environmental management. But geodesign makes this easier by anthropogenic earth issues by allowing us to inventory and making it an integral part of the workflow, both shortening the display large, complex spatial datasets. We can also analyze the cycle time of the design process and improving the quality of the potential interplay between various factors, getting us closer to results.

a true understanding of how our dynamic earth systems may change in the coming decades and centuries.

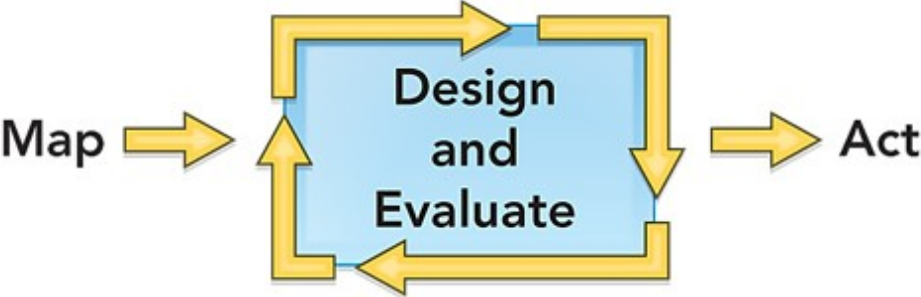
The Geodesign Process

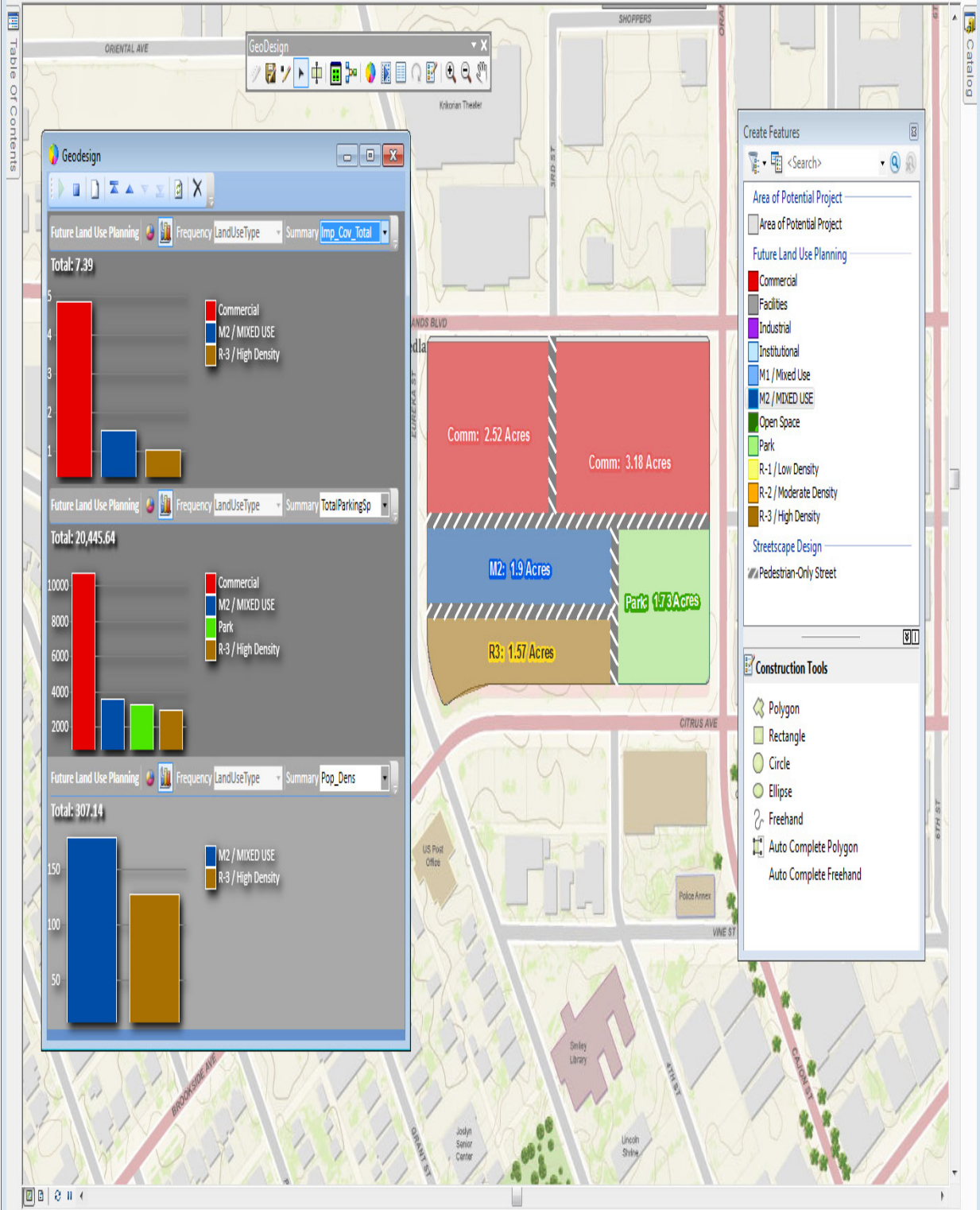
Geodesign borrows concepts from landscape architecture, When an idea is proposed with geographic consequences—a environmental studies, geography, planning, regenerative housing development, a shopping center, a road, a wildlife studies, and integrative studies.

Much like GIS and environmental preserve, a farm—it first goes through a design process. After Understanding Earth April 2012

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it is initially designed, a project is vetted against geographic phase, critical factors are instead taken into consideration up constraints.

front. The quality of the results improves because the project is designed around, in concert with, and/or to fully leverage A typical project will go through many iterations of design and certain geographic, environmental, and social features while evaluation. As the constraints of geography on the project—and simultaneously minimizing undesirable impacts to those same the impacts of the project on geography—are revealed, the features.

design is continually refined. Because design and evaluation have traditionally been separate disciplines, this phase of a project can be time-consuming, inefficient, and tedious.

What if we could reduce the time and tedium of these iterations by integrating design directly into the GIS workflow?

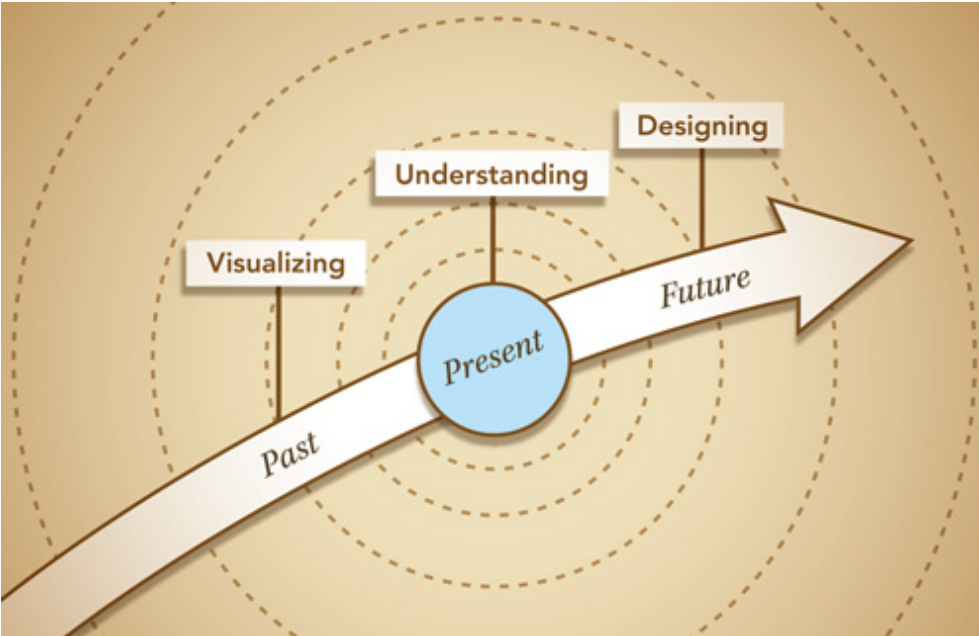
This integration—which we refer to as the geodesign workflow—

is a promising alternative to traditional processes. It allows designers and evaluators to work closely together to significantly Interactive geodesign tools let us design the future while considering geographic constraints.

lessen the time it takes to produce and evaluate design iterations.

Cycle time is shortened because geodesign moves analysis to Combining the wealth of available data about our world with an earlier stage in the design process. Rather than analyzing sophisticated analysis and management tools is the prescription the potential effects of a proposed project after the design Understanding Earth April 2012

Designing Our Future



for understanding and shaping the future of our planet—an and vegetation, but also on the availability of resources," McHarg anthropogenic future where advances in human society, states, describing an early environmental planning study in his technology, and so on, are designed in close col aboration with book [A Quest for Life. He cal s his discovery of chronology, or nature, resulting in the best of the possible future worlds. And the order or sequence of geographic features through time, "a this is what "designing our future" means. It's a huge task and a most revelatory instrument for understanding the environment, delicate balance, for sure, but with help from GIS and geodesign diagnosing, and prescribing." McHarg's chronology is an tools, we readily accept that chal enge. Because, frankly, we have important concept to grasp, as it can lead us to a deeper no other choice.](#)

understanding of structure and meaning in the landscape.

Traveling through Time

The concept of a time machine as used in science fiction has certainly captured our col ective imagination. But the science behind time travel is dubious at best. Although we can't actually physically

move backward or forward in time, we can at least experience some of the thrills—and benefits—of time travel with GIS.

Geospatial professionals are well versed in the visualization of spatial relationships and dependencies. But it is equally important, when looking for relationships and dependencies, to examine proximity in time. McHarg put great emphasis on chronology, or the placing of geographic layers in chronological sequence. We need to move beyond passively trying to "predict" the future toward showing relationships, dependencies, and causation actively creating or "designing" the future.

through time.

"We found the earliest events, mainly of geological history, had Using chronology to visualize the past is certainly an important pervasive and influential effects, not only on physiography, soils, tool to help us understand the present. But can we do even more Understanding Earth April 2012

Designing Our Future

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with this geographic knowledge? Can we use it to predict the past to both understand the present and envision the future. As future?

someone said at the 2012 [GeoDesign Summit](#), "By designing geography, you're designing history." We need to embrace this The Problem of Prediction

idea.

Predicting the future is an elusive exercise. Just pick up an old magazine from the 1960s that talks about what life will be like in

"In a very real way, designers create the human environment,"

the year 2000, or watch a movie or read a book set 50 years out.

says [William McDonough](#) in [Twenty-First Century Design](#). "They While highly entertaining, nobody ever gets it right. Very few get make the things we use, the places we live and work, our modes even remotely close.

of communication and mobility." From a building to a highway, from a city to a utility network, geographic design decisions we The real problem of predicting the future is one of complexity.

make today can have huge consequences for the lives of future

"There really is only one past," notes [Stephen Ervin](#) of Harvard generations.

University's Graduate School of Design, "but there are multiple futures." So if predicting the future is so difficult, impractical, or We have the geospatial tools and techniques in place to downright impossible, should we even bother trying? Is there understand how the past has created the present, and through anything to gain from such folly?

the thoughtful and careful application of these same tools and techniques, we can more actively design the future. Trying to Perhaps we need to move beyond prediction and find a different shape our current actions to ensure the best possible future is way to think about our relationship with the future. "The future a delicate balancing act, and there are many complex factors can't be predicted," says environmental scientist and systems to consider. But achieving that balance offers hope for a future thinker [Donella Meadows](#), "but it can be envisioned and brought ideally suited to both humans and the environment.

lovingly into being."

Instead of asking what the world might look like in the future, we Envisioning the Future

should begin asking ourselves: What do we want the world to As McHarg states in his book [To Heal the Earth](#), "Processes, laws, look

like? And how can we make it happen?

and time reveal the present." Meadows echoes this idea, noting,

"We experience now the consequences of actions set in motion yesterday and decades ago and centuries ago." Projecting this same concept of chronology forward in time, we can study the
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A New Relationship

For all the successes of conservation, this technique is not without
Our use of and reliance on technology has moved us toward a its
problems. It has resulted in fragmented and incomplete new
relationship with the environment. In countless ways, both
ecosystems that in some cases are no longer self-sustaining and
seen and unseen, the ecosystems we once saw as "natural"

continue to be heavily impacted by the hand of man.

have become strange hybrids—part natural, part man-made,
Technology's Role

struggling for balance under the watchful eye of human Despite all
this, technology isn't all bad for the environment. As management.

the human world becomes universally instrumented, we are As we
move forward in this more mutually beneficial relationship amassing
vast amounts of data. We need the ability to manage with the
environment, the dynamic is evolving—from using this ever-
increasing volume of data so that we can discover, we technology to
merely exploit our surroundings toward the can learn, and we can use
this valuable information to act in thoughtful application of technology
to actively manage, design, more responsible ways. The key to
solving this vast information and sustain our surroundings. This new

relationship with the problem is information technology—and specific to addressing environment features a much tighter integration between humans ecosystem issues and managing the human-influenced landscape and technology, where all decisions are carefully designed to is GIS technology.

maximize the benefit—and minimize the harm—to both humans It's true that technology has made our world more complex.

and natural systems.

But technology can also serve the purpose of managing this An Informed Environment

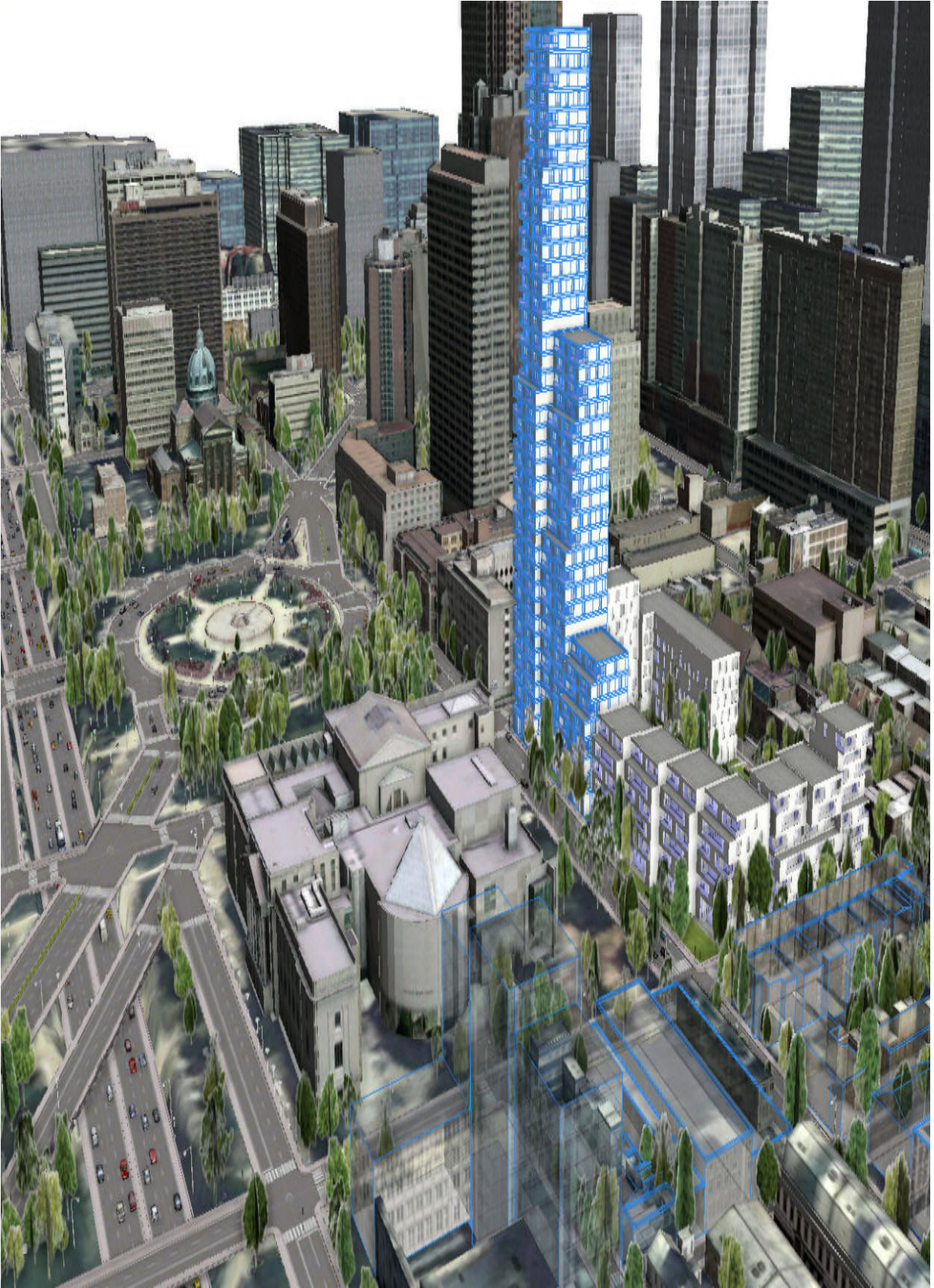
complexity. GIS technology now permits a science-based When man began to understand the overwhelming effects of approach to ecosystem management that was unthinkable until mass exploitation on natural earth systems, he reacted with recently. We use it to predict the likely locations of endangered conservation. This era began with the preservation of significant, animals, to model how plant communities might shift due to dramatic, and unique examples of ecosystems, perhaps best climate change, and even to design places where man and nature exemplified by national parks such as Yel owstone and Yosemite.

can coexist more peacefully. Mapmaking and geographic analysis This trend continued with the preservation of remnant pieces are not new, but GIS technology helps perform these tasks better of ecosystems—the setting aside of the last remaining bits of and faster than was possible using the old manual methods—an wildness.

increase in efficiency and accuracy sorely needed to address the tough problems we face in our increasingly complex world.

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Designing Our Future



We tend to think of "natural environment" and "human technology" as two opposing, almost mutually exclusive ends of the spectrum. But as technology becomes more pervasive in our world and more tightly integrated with our very existence, in fact the opposite is true. If we do it correctly, this integration will allow humans to enter a more mutually beneficial relationship with the environment. We are moving forward as a species, toward a time when technology will play an essential role in sustaining the habitat of all species—including humans—and actually help us to design that habitat.

As Marina Gorbis notes in *Human Plus Machine*, technology amplifies our capabilities, "enabling us to do things we never dreamed of doing before." For us to meet the monumental challenges of the future, David Kirkpatrick, author of *The GIS* technology helps us make sense of a complex world.

Facebook Effect, states that "We will only be successful if we unreservedly embrace technology and innovation as essential The New Natural

tools." Yet as [Louis Gerstner](#), notes, we need to approach this In the twenty-first century, information technology is becoming relationship carefully: "Computers are magnificent tools for the our most valuable tool for managing complexity and designing realization of our dreams, but no machine can replace the human a better world. "Technology offers a continually, if unevenly, spark of spirit, compassion, love, and understanding."

expanding domain of increasing human control and power in the world, and in the process, technology continually transforms From a simple spear to a smartphone, tools extend our abilities, the natural and social worlds," say Braden Al enby and Daniel but we need to be careful to not lose touch with what actually Sarewitz in *The Techno-Human Condition*. "Technology makes us human. As technology becomes more tightly integrated embodies the modern ideal of applying rationality to the into virtually everything we do, we need to understand that it's betterment of humankind."

not a blessing, nor is it a curse—it's simply a tool of our own creation, a tool to help us move down the path toward our Understanding Earth
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destiny. Or, as Al enby and Sarewitz note, "Technology is neither what exists inside and outside buildings, as well as how the answer nor the question, it's just the condition."

things connect to the city and how all of these things change through time.

The Future of Cities

- Cities as ecosystems—Cities are the places where most of Seven bil ion. That number has received a lot of attention recently us now spend the vast majority of our lives. They have in as global population has grown past this mark. But lost in the fact become man-made ecosystems. Recognition of cities as media coverage of this milestone was another, perhaps even the primary habitat for the human species is leading to new more fascinating global statistic: more than 50 percent of those approaches to their management and design. GIS technology 7 bil ion people now live in cities, a number projected to grow has long been used to map, study, analyze, and manage more than 75 percent during this century. In fact, there will be at natural ecosystems. It only seems logical to manage, model, least 19 cities in the world with a population greater than and design our new man-made ecosystems with the same 20 mil ion by the end of the twenty-first century. Cities are human tried and true tools.

destiny.

- Buildings as microcities—As our cities are growing in size and Clearly, cities will play an increasingly important role in our future complexity, so too are the buildings that make up much of survival. Cities offer easier access to services, and urban dwel ers the fabric of

the city. In effect, many buildings and facilities are more efficient consumers of limited resources. But as our are becoming small cities themselves, and they need to be cities become more populous and more numerous, how do we designed and managed as such. GIS tools, used successfully best manage this complexity?

for many years in fields such as environmental analysis and landscape planning, also support a broad range of We need to start thinking about cities in a different way: applications inside and outside buildings and facilities.

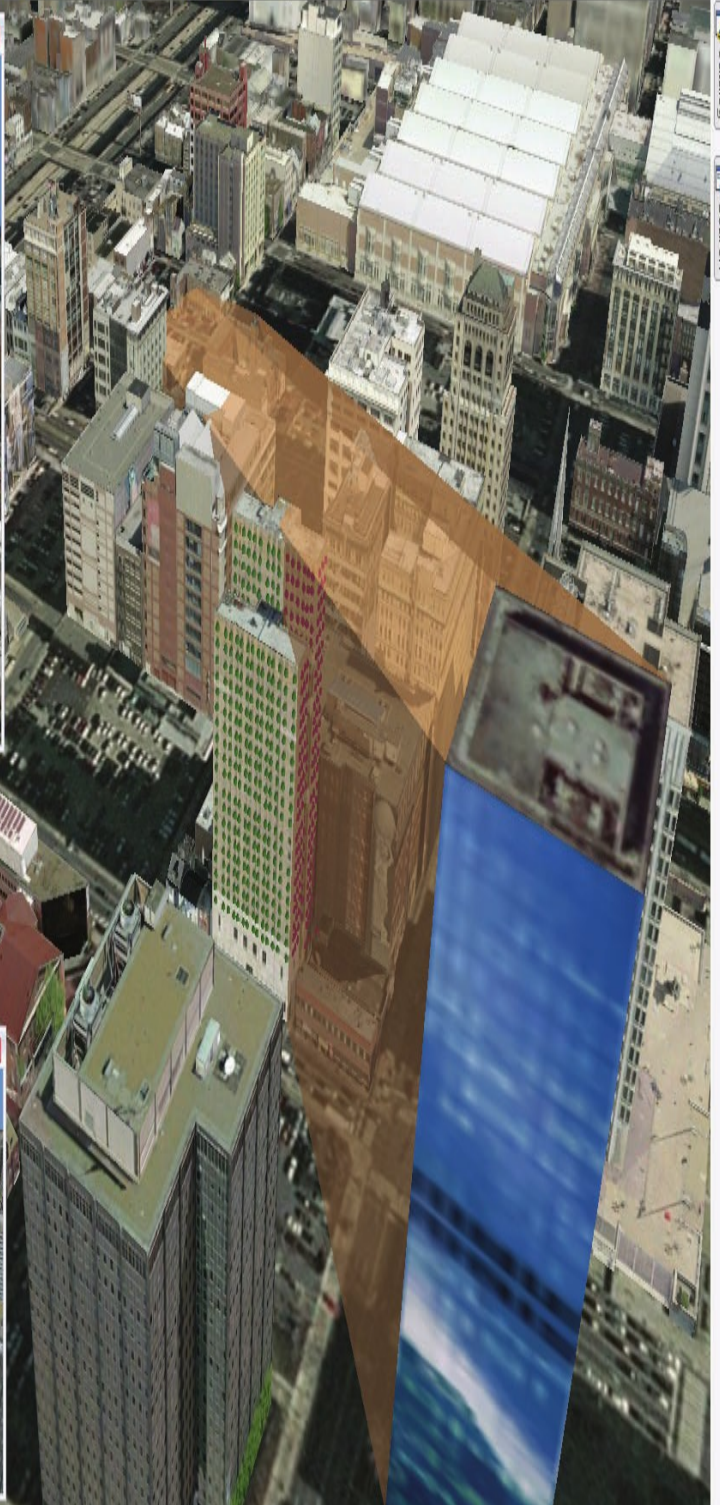
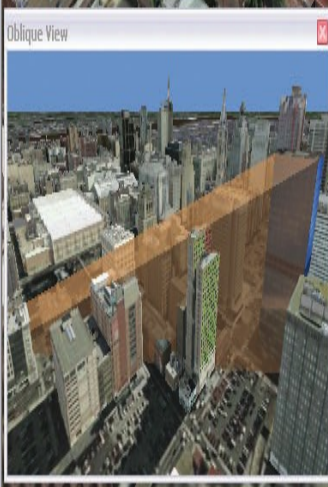
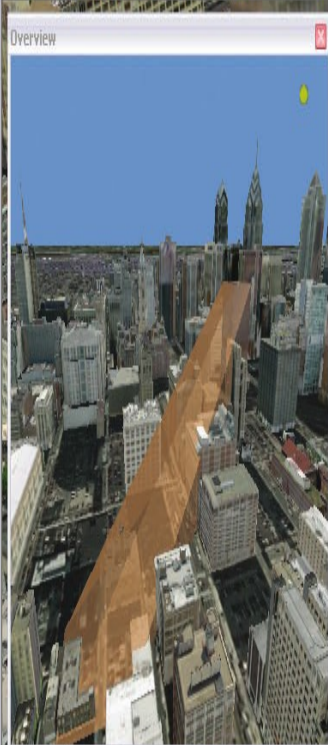
- Reimagining the canvas—Fundamental to changing the way
- An engaged citizenry—Smart cities of the future will be we think about cities is a reimagining of the way we abstract those where citizens are engaged in their design and them. GIS technology gives us a powerful new context evolution, where the col ective intel igence of the masses is for extending our traditional methods of abstracting the leveraged and everyone can actively participate in shaping geography of cities—a new canvas that includes everything the community. GIS technology has already proved to be an that lies below, on, above, and around the city, including Understanding Earth April 2012

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Catalog Search

effective tool in supporting citizen engagement. Intelligent web maps are acknowledged as catalysts 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 future cities—Geodesign is 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 GIS helps us think about cities in a different way.

deeper understanding of the implications of one design over long-term impacts on the natural environment. As an integrative another. Combining the strengths of data management and platform for the management and analysis of all things spatial, analysis with a strong design and automation component is GIS technology can help meet this challenge.

fundamental to designing the cities of the future.

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

machinery, and people, with countless spatial and temporal relationships and dependencies. They require progressively more

The Climate Challenge

sophisticated tools for their design and management. They are complex systems where we humans spend an increasing amount Earth's climate has undergone radical changes in the distant as of our lives.

well as the recent past and is almost certain to undergo more radical changes in the not-too-distant future. As industrialization, Our chal

enge is to design our man-made ecosystems to achieve population, and urbanization continue to increase, so too will the maximum benefit to society while minimizing short- and stressors on the environment, such as pollution. Such change in Understanding Earth April 2012

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climate and environmental quality could have huge implications describing conditions at particular locations on the planet at for quality of life. Regardless of where each of us stands on the particular points in time.

often politically charged issue of global climate change, we owe For years, scientists have been using sophisticated computer it to ourselves and our children to take an informed look at the models in an attempt to visualize the future of earth's climate.

scientific data and develop actionable, intelligent alternatives.

The output of a particular model can be enlightening, but using We live in an age of readily and freely available information. The GIS to combine data from multiple models and sources, both Internet has given us unprecedented awareness of and access to past and future, gives us the best chance for a comprehensive vast quantities of climate data. Never before have scientists and and accurate vision of what the future holds for our planet.

nonscientists had such easy and open access to the data and tools needed to study the earth's climate. Both past observations **The Next Generation**

and future predictions are useful in studying climate change.

Many industries have suffered during the current economic Examining and cross-referencing past and future data can help downturn. So why is it that during this same period, demand for

quantify changes already occurring as well as predict patterns geospatial technology professionals has grown significantly?

and trends that could impact climate in the near- and long-term future.

We think that this trend is due to the growing understanding of the value of spatial information and analysis. There are many For decades or longer, and for thousands of locations around reasons to implement GIS, but the benefits that we see driving the globe, humans have been keeping careful records of rainfall , organizations in lean times are cost savings resulting from greater temperature, lake levels, streamflows, and so on. Beyond these efficiency. And as we come out of this economic downturn, the historical records, additional records of climate change stretch efficiencies realized from GIS will become a standard way of back even farther; consider the fields of dendrochronology, which doing business, so the need for geospatial professionals will measures the size of tree rings and reveals climate data stretching increase even more.

back for thousands of years, and palynology, which examines changes in the type and distribution of fossil pollen and gives us Government has long been at the forefront of this movement, clues about climate that go back millions of years. The result of and there will be opportunities here for people with geospatial all this information collection and research is vast stores of data knowledge, most notably in the area of homeland security and the agencies concerned with increased transparency and Understanding Earth April 2012

Designing Our Future



accountability. But we're now seeing a huge shift in momentum in the commercial arena. Many of the future career opportunities for geospatial professionals will be in the private sector, as businesses increasingly realize the benefits that government has understood for some time.

The current high unemployment rate is sending a lot of experienced workers "back to school" to learn new skills more relevant to the twenty-first-century workplace. This is one factor driving the growth of focused geospatial programs at universities and community colleges, both at the degree level and the certificate level. These programs are doing a great service by training the geospatial workforce of tomorrow. They are also providing many opportunities for seasoned geospatial professionals to take on new roles themselves—passing on their knowledge by instructing and teaching the next generation created for spatial thinkers in many areas.

of geospatial professionals.

A New Understanding

But the career opportunities here are not just for the people who Maps have long been used by man for communicating and sit in front of keyboards and "do GIS." It's much bigger than that.

understanding. Today, modern mapping and GIS technology The real growth opportunity is in the area of spatial thinking. As drive a new relationship between humans and the environment, people in all types of positions become more familiar with the giving us the geographic understanding we need to proactively value of geography, they begin to ask more intel igent questions design a better future.

about the world, and they begin to make better informed decisions.

The future looks bright for the next generation of spatial thinkers.

And these are the people who are going to change the world.

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About the Authors

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.

Matt Artz writes for Esri about the value of using GIS technology to advance scientific understanding.

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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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Printed in USA

G53017 ESRI4/12ek

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