The Digital Earth: Understanding our planet in the 21st Century

by Al Gore

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A new wave of technological innovation is allowing us to capture, store, process and display an unprecedented amount of information about our planet and a wide variety of environmental and cultural phenomena. Much of this information will be "georeferenced" - that is, it will refer to some specific place on the Earth's surface.

The hard part of taking advantage of this flood of geospatial information will be making sense of it. - turning raw data into understandable information. Today, we often find that we have more information than we know what to do with. The Landsat program, designed to help us understand the global environment, is a good example. The Landsat satellite is capable of taking a complete photograph of the entire planet every two weeks, and it's been collecting data for more than 20 years. In spite of the great need for that information, the vast majority of those images have never fired a single neuron in a single human brain. Instead, they are stored in electronic silos of data. We used to have an agricultural policy where we stored grain in Midwestern silos and let it rot while millions of people starved to death. Now we have an insatiable hunger for knowledge. Yet a great deal of data remains unused.

Part of the problem has to do with the way information is displayed. Someone once said that if we tried to describe the human brain in computer terms, it looks as if we have a low bit rate, but very high resolution. For example, researchers have long known that we have trouble remembering more than seven pieces of data in our short-term memory. That's a low bit rate. On the other hand, we can absorb billions of bits of information instantly if they are arrayed in a recognizable pattern within which each bit gains meaning in relation to all the others — a human face, or a galaxy of stars.

The tools we have most commonly used to interact with data, such as the "desktop metaphor" employed by the Macintosh and Windows operating systems, are not really suited to this new challenge. I believe we need a "Digital Earth". A multi-resolution, three-dimensional representation of the planet, into which we can embed vast quantities of geo-referenced data.

Imagine, for example, a young child going to a Digital Earth exhibit at a local museum. After donning a head-mounted display, she sees Earth as it appears from space. Using a data glove, she zooms in, using higher and higher levels of resolution, to see continents, then regions, countries, cities, and finally individual houses, trees, and other natural and man-made objects. Having found an area of the planet she is interested in exploring, she takes the equivalent of a "magic carpet ride" through a 3-D visualization of the terrain. Of course, terrain is only one of the many kinds of data with which she can interact. Using the systems' voice recognition capabilities, she is able to request information on land cover, distribution of plant and animal species, real-time weather, roads, political boundaries, and population. She can also visualize the environmental information that she and other students all over the world have collected as part of the GLOBE project. This information can be seamlessly fused with the digital map or terrain data. She can get more information on many of the objects she sees by using her data glove to click on a hyperlink. To prepare for her family's vacation to Yellowstone National Park, for example, she plans the perfect hike to the geysers, bison, and bighorn sheep that she has just read about. In

fact, she can follow the trail visually from start to finish before she ever leaves the museum in her hometown.

She is not limited to moving through space, but can also travel through time. After taking a virtual field-trip to Paris to visit the Louvre, she moves backward in time to learn about French history, perusing digitized maps overlaid on the surface of the Digital Earth, newsreel footage, oral history, newspapers and other primary sources. She sends some of this information to her personal e-mail address to study later. The time-line, which stretches off in the distance, can be set for days, years, centuries, or even geological epochs, for those occasions when she wants to learn more about dinosaurs.

Obviously, no one organization in government, industry or academia could undertake such a project. Like the World Wide Web, it would require the grassroots efforts of hundreds of thousands of individuals, companies, university researchers, and government organizations. Although some of the data for the Digital Earth would be in the public domain, it might also become a digital marketplace for companies selling a vast array of commercial imagery and value-added information services. It could also become a "collaboratory"-- a laboratory without walls — for research scientists seeking to understand the complex interaction between humanity and our environment.

Technologies needed for a Digital Earth

Although this scenario may seem like science fiction, most of the technologies and capabilities that would be required to build a Digital Earth are either here or under development. Of course, the capabilities of a Digital Earth will continue to evolve over time. What we will be able to do in 2005 will look primitive compared to the Digital Earth of the year 2020. Below are just a few of the technologies that are needed:

Computational Science: Until the advent of computers, both experimental and theoretical ways of creating knowledge have been limited. Many of the phenomena that experimental scientists would like to study are too hard to observe - they may be too small or too large, too fast or too slow, occurring in a billionth of a second or over a billion years. Pure theory, on the other hand, cannot predict the outcomes of complex natural phenomena like thunderstorms or air flows over airplanes. But with high-speed computers as a new tool, we can simulate phenomena that are impossible to observe, and simultaneously better understand data from observations. In this way, computational science allows us to overcome the limitations of both experimental and theoretical science. Modeling and simulation will give us new insights into the data that we are collecting about our planet.

Mass Storage: The Digital Earth will require storing quadrillions of bytes of information. Later this year, NASAs Mission to Planet Earth program will generate a terrabyte of information each day. Fortunately, we are continuing to make dramatic improvements in this area.

Satellite Imagery: The Administration has licensed commercial satellites systems that will provide 1-meter resolution imagery beginning in early 1998. This provides a level of accuracy sufficient for detailed maps, and that was previously only available using aerial photography. This technology, originally developed in the U.S. intelligence community, is incredibly accurate. As one company put it, "It's like having a camera capable of looking from London to Paris and knowing where each object in the picture is to within the width of a car headlight."

Broadband networks: The data needed for a digital globe will be maintained by thousands of different organizations, not in one monolithic database. That means that the servers that are participating in the Digital Earth will need to be connected by high-speed networks. Driven by the explosive growth of Internet traffic, telecommunications carriers are already experimenting with 10 gigabit/second networks, and terrabit networking technology is one of the technical goals of the Next Generation Internet initiative. The bad news is that it will take a while before most of us have this kind of bandwidth to our home, which is why it will be necessary to have Digital Earth access points in public places like children's museums and science museums.

Interoperability: The Internet and the World Wide Web have succeeded because of the emergence of a few, simple, widely agreed upon protocols, such as the Internet protocol. The Digital Earth will also need some level of interoperability, so that geographical information generated by one kind of application software can be read by another. The GIS industry is seeking to address many of these issues through the Open GIS Consortium.

Metadata: Metadata is "data about data." For imagery or other georeferenced information to be helpful, it might be necessary to know its name, location, author or source, date, data format, resolution, etc. The Federal Geographic Data Committee is working with industry and state and local government to develop voluntary standards for metadata.

Of course, further technological progress is needed to realize the full potential of the Digital Earth, especially in areas such as automatic interpretation of imagery, the fusion of data from multiple sources, and intelligent agents that could find and link information on the Web about a particular spot on the planet. But enough of the pieces are in place right now to warrant proceeding with this exciting initiative.

Potential Applications

The applications that will be possible with broad, easy to use access to global geospatial information will be limited only by our imagination. We can get a sense of the possibilities by looking at today's applications of GIS and sensor data, some of which have been driven by industry, others by leading-edge public sector users:

Conducting virtual diplomacy: To support the Bosnia peace negotiations, the Pentagon developed a virtual-reality landscape that allowed the negotiators to take a simulated aerial tour of the proposed borders. At one point in the negotiations, the Serbian President agreed to a wider corridor between Sarajevo and the Muslim enclave of Gorazde, after he saw that mountains made a narrow corridor impractical.

Fighting crime: The City of Salinas, California has reduced youth handgun violence by using GIS to detect crime patterns and gang activity. By collecting information on the distribution and frequency of criminal activities, the city has been able to quickly redeploy police resources.

Preserving biodiversity: Planning agencies in the Camp Pendelton, California region predict that population will grow from 1.1 million in 1990 to 1.6 million in 2010. This region contains over 200 plants and animals that are listed by federal or state agencies as endangered, threatened, or rare. By collecting information on terrain, soil type, annual rainfall, vegetation, land use, and ownership, scientists modeled the impact on biodiversity of different regional growth plans.

Predicting climate change: One of the significant unknowns in modeling climate change is the global rate of deforestation . By analyzing satellite imagery, researchers at the University of New Hampshire, working with colleagues in Brazil, are able to monitor changes in land cover and thus determine the rate and location of deforestation in the Amazon. This technique is now being extended to other forested areas in the world.

Increasing agricultural productivity: Farmers are already beginning to use satellite imagery and Global Positioning Systems for early detection of diseases and pests, and to target the application of pesticides, fertilizer and water to those parts of their fields that need it the most. This is known as precision farming, or "farming by the inch."

The Way Forward

We have an unparalleled opportunity to turn a flood of raw data into understandable information about our society and out planet. This data will include not only high-resolution satellite imagery of the planet, digital maps, and economic, social, and demographic information. If we are successful, it will have broad societal and commercial benefits in areas such as education, decision-making for a sustainable future, land-use planning, agricultural, and crisis management.

The Digital Earth project could allow us to respond to manmade or natural disasters - or to collaborate on the long-term environmental challenges we face.

A Digital Earth could provide a mechanism for users to navigate and search for geospatial information - and for producers to publish it. The Digital Earth would be composed of both the "user interface" - a browsable, 3D version of the planet available at various levels of resolution, a rapidly growing universe of networked geospatial information, and the mechanisms for integrating and displaying information from multiple sources.

A comparison with the World Wide Web is constructive. [In fact, it might build on several key Web and Internet standards.] Like the Web, the Digital Earth would organically evolve over time, as technology improves and the information available expands. Rather than being maintained by a single organization, it would be composed of both publically available information and commercial products and services from thousands of different organizations. Just as interoperability was the key for the Web, the ability to discover and display data contained in different formats would be essential.

I believe that the way to spark the development of a Digital Earth is to sponsor a testbed, with participation from government, industry, and academia. This testbed would focus on a few applications, such as education and the environment, as well as the tough technical issues associated with interoperability, and policy issues such as privacy. As prototypes became available, it would also be possible to interact with the Digital Earth in multiple places around the country with access to high-speed networks, and get a more limited level of access over the Internet.

Clearly, the Digital Earth will not happen overnight.

In the first stage, we should focus on integrating the data from multiple sources that we already have. We should also connect our leading children's museums and science museums to high-speed networks such as the Next Generation Internet so that children can explore our planet. University researchers would be encouraged to partner with local schools and museums to enrich the Digital Earth project — possibly by concentrating on local geospatial information.

Next, we should endeavor to develop a digital map of the world at 1 meter resolution.

In the long run, we should seek to put the full range of data about our planet and our history at our fingertips.

In the months ahead, I intend to challenge experts in government, industry, academia, and non-profit organizations to help develop a strategy for realizing this vision. Working together, we can help solve many of the most pressing problems facing our society, inspiring our children to learn more about the world around them, and accelerate the growth of a multi-billion dollar industry.