APOGEO SPATIAL

ELEVATING GLOBAL AWARENESS

The "Tragedy of the Commons" for Government Open Data

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– Perry Peterson, the PYXIS innovation *p. 22*

"The World Bank has been receptive...to the use of Earth observation imagery to evaluate geophysical aspects of its funded projects, and its new role as participating organization in GEO resonates well."

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FORMERLY Imaging NOTES

Sumy, Oblast, Ukraine, showing ice on Feb. 17, 2016, courtesy of Planet Labs, Inc.

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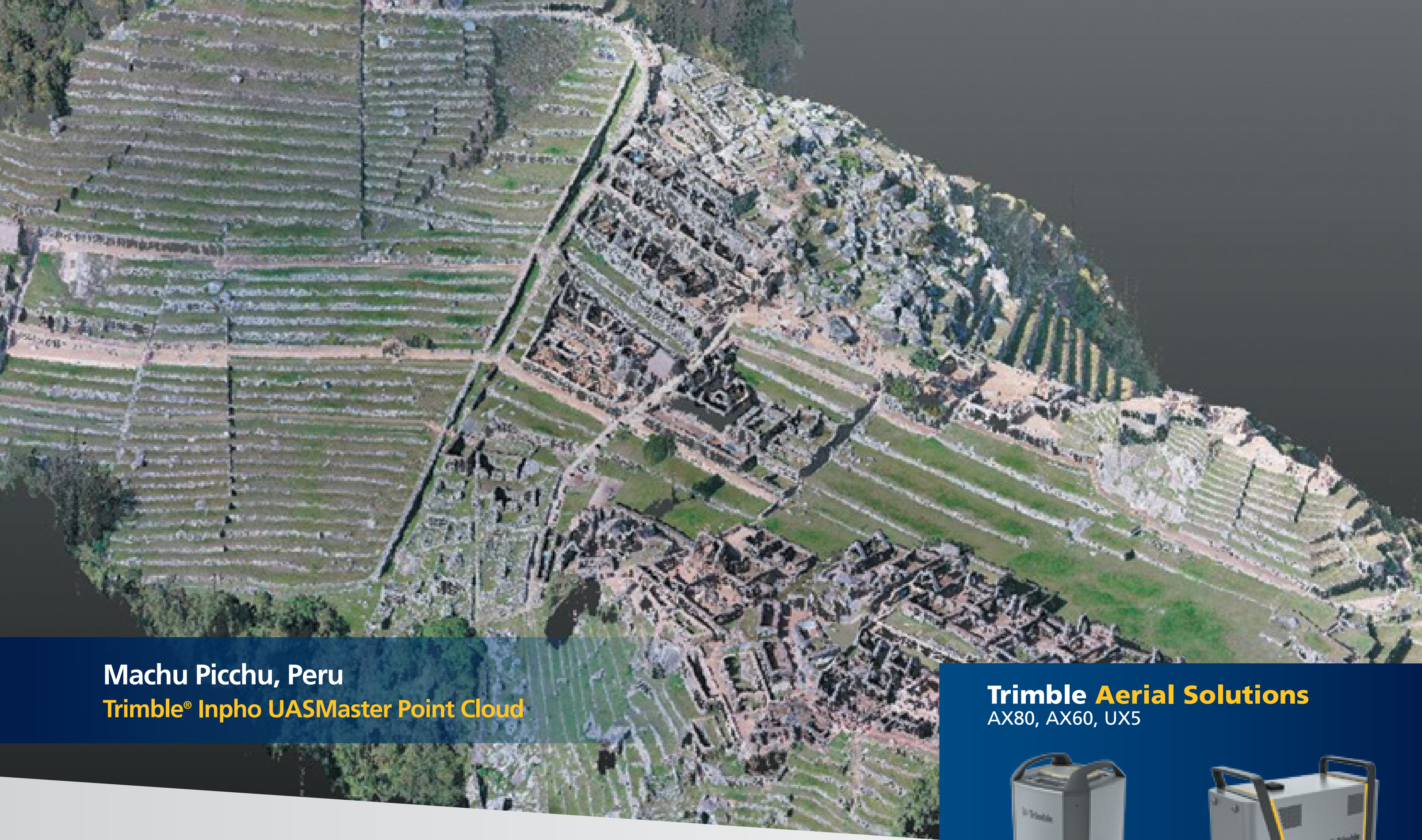

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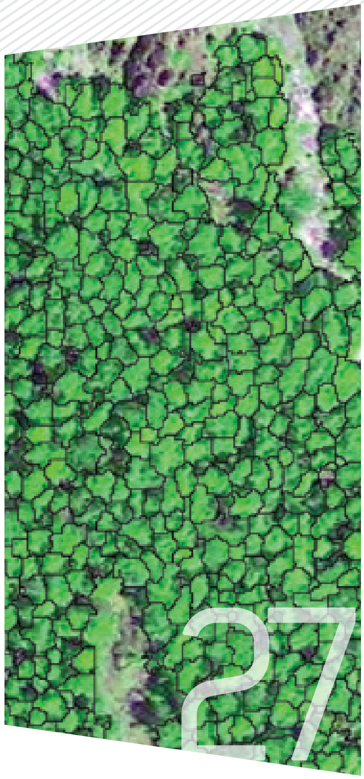

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Columns

Features

COVER IMAGE

Sumy, Ukraine

SUMY IS A CITY IN NORTHEASTERN UKRAINE, in the Sumy oblast. An oblast is an administrative division corresponding to an autonomous province in the former Soviet Union. The lat/long of the area is 50.9077 and 34.7981.

This region is known for its rich land and agriculture. The fields in summer will produce potatoes, grains, sunflowers and sugar beets.

This winter image was taken Feb. 17, 2016, and is courtesy of Planet Labs, Inc.

APOGEO SPATIAL

Formerly Imaging NOTES

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MISSION

Apogeo Spatial communicates the power of geospatial tools and technologies in managing the world's environment and scarce resources, so that the global population has the security of water, food, and energy.

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Apogeo Spatial has a partnership with Secure World Foundation (www.swfound.org).

Apogeo is affiliated with the Alliance for Earth Observations, a program of The Institute for Global Environmental Strategies (www.strategies.org).

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OGC Provides New Standard for “Digital Earth”

DEAR REMOTE SENSING AND LOCATION PROFESSIONALS,

In this issue, we are excited to announce that the OGC has a new important standard for “Digital Earth” – all the various representations of our world that exist online with geospatial accuracy. It’s called the Discrete Global Grid System (DGGS); the public comment period just concluded, and soon it will go to a vote for approval. This is exciting and much needed; read all about it on page 22.

On page 16, we continue our series exploring ways to manage and visualize geospatial data. This series began because of the news that Google Earth API / Enterprise would be deprecated, and it continues because there are many companies offering various ways of managing and visualizing data, and doing so all in one place may not be the solution. Of course, everything depends on what the users need. In this ongoing series, we are providing relevant information so that readers will be able to make educated decisions.

In the Fall 2015 issue, we covered VRICON’s Globe in 3D, and Esri’s ArcGIS Earth. In this issue, we cover Galdos Systems’ INdicio, Skyline Software Systems’ TerraExplorer and SkylineGlobe, as well as the contributions of Onix Networking Corp. Companies have many options when it comes to organizing and visualizing geospatial data, and we will continue to share them in this series moving forward. Please provide feedback on the *Apogeo Spatial* LinkedIn company page.

We are pleased to publish the viewpoint of Dr. Tyrone Grandison, whose role as Deputy Chief Data Officer at the U.S. Department of Commerce gives him unique insight into the U.S. Government’s policies and procedures. In his Opinion/Editorial, he shares his belief that the government provides a significant amount of “free” data, which is not properly appreciated or understood by citizens, or even by businesses that benefit from the use of this data. Read more on page 10.

Our partnership with Secure World Foundation provides us with unique access to the meetings of the Group on Earth Observations, the intergovernmental organization that is leading the worldwide effort to build a Global Earth Observation System of Systems (GEOSS), which will address nine societal benefit areas defined by the United Nations. The report from the 2015 Ministerial Summit in Mexico City is on page 8. For more information, see www.earthobservations.org. Data is being housed at www.geoportal.org.

Also in the last issue, we announced that for every magazine that we print, we are replacing trees that we use, via PrintReleaf. This wonderful organization has just received approval for their patent, confirming that the technology solutions and systems which they are using to measure printer resources and transact environmental offsets were designed in such unique ways that they warrant the legal protection. “When we launched PrintReleaf, we set the goal of creating the world’s first platform to automate global reforestation for paper-based products,” said Jordan Darragh, founder and CEO. “Being awarded a patent is ultimate validation that we’ve met this particular goal, one for which we are very grateful.”

Thanks for reading. Please send editorial ideas and feedback to myrna@apogeospatial.com.

Sincerely,
Myrna James Yoo

Myrna James Yoo
Publisher and
Managing Editor
Apogeo Spatial
and *LBx Journal*
Owner
Blueline Publishing LLC
Myrna@ApogeoSpatial.com

Michael K. Simpson, PhD
Executive Director
Secure World Foundation
Broomfield, Colo.
www.swfound.org

GEO Moves Forward

A REPORT FROM MEXICO CITY

THE MEXICO CITY DECLARATION ADOPTED AT THE Group on Earth Observations (GEO) Ministerial Summit in November 2015 promises a dynamic Earth observation (EO) agenda for the next four years.

Approved by consensus, this brief, two-page document highlights a number of top political priorities for the use and development of Earth observation technology. Among these, international data sharing, climate monitoring, and support for the 2030 Development agenda all were mentioned at least twice.

The Ministers led off their declaration with the need for data sharing stating, "full and open access to Earth observation data, information and knowledge is crucial for humanity," and later reaffirmed their support for GEO's Data Sharing Principles, which are still undergoing refinement. They also took time to recognize what they felt were positive developments in the broader international sharing of data by welcoming "the global efforts to improve data availability for developing countries such as through the European Union's Copernicus Programme, the China-Brazil Earth Resources Satellite, and the (U.S.) Shuttle Radar Topography Mission." The tone of debate and discussion prior to the adoption of the declaration made it clear that its emphasis on data sharing was broadly supported by both national representatives and participating organizations.

The role of GEO and the Earth observation systems it is tasked with knitting into a Global Earth Observation System of Systems (GEOSS) in addressing climate change was also a frequent topic of comment from the floor of both the Ministerial Summit and the GEO Plenary Session that preceded it. Strong support was voiced for increasing the monitoring of climate-related data and expanding research into ways space-based assets could expand our knowledge of factors impacting climate change. Such sentiment was well supported in the text of the declaration with the United Nations Framework Convention on Climate Change highlighted among a small number of institutions singled out for focused support from the GEO community. The declaration also emphasized the importance of EO-facilitated climate projections for development planners in the world's less developed countries.

Although concerns about climate change seemed to be the number one concern among delegates from the developed world, the ambitious economic development objectives of the UN's 2030 Global Goals for Sustainable Development received top-of-mind attention from those representing the developing world. Their message was not lost on the Ministers, whose declaration included specific reference to economic development and the cooperation they wanted GEO to provide for it no fewer than six times. They also acknowledged the need for developing countries themselves to increase the involvement in the GEO community and in the development of applications that can improve the human condition. Here they cited regional initiatives like AfriGEOSS, AmeriGEOSS and GEOSS Asia Pacific as positive developments.

Other important priorities emerging from the GEO meetings in Mexico City include the growing interest in partnerships with private sector initiatives, the first admission of international

> The World Bank has been receptive for some time to the use of Earth observation imagery to evaluate geophysical aspects of its funded projects and its new role as a participating organization in GEO resonates well with the increased focus on the needs of data users.

organizations as participating organizations, the adoption of a new strategic plan, and a growing focus on the needs of users of GEO's data and information output.

In addition to the call for public–private partnerships that has been heard at GEO meetings for some time, the November 2015 sessions heard several calls for including private, for-profit institutions in the eligibility list for election as participating organizations. Although this proposal, advanced by U.S. GEO Principal, Kathy Sullivan, Administrator of NOAA,was not adopted, Dr. Sullivan was encouraged to develop the proposal further and bring it back at the next plenary session. Importantly, hers was not the only voice raised in support of the idea, which nonetheless was also met by some skepticism and concern from delegates who worried that for-profit missions might conflict with GEO's humanitarian or development objectives. This is certainly a debate worth following as it resumes in the next plenary scheduled for November 2016.

One very important development was the declaration's call for improved integration of GEO's efforts with those of the economic development banks. A clear message that this idea was broadly accepted by the GEO community was delivered when the World Bank was admitted as a participating organization during the plenary session. The World Bank has been receptive for some time to the use of Earth observation imagery to evaluate geophysical aspects of its funded projects and its new role as a participating organization in GEO resonates well with the increased focus on the needs of data users.

This latter theme received considerable support both from discussions at the plenary and from the Ministerial Summit. After ten successful years of developing protocols, systems, and data gathering technologies during GEO's first decade, it is clear that the needs of those using and seeking to use Earth observation data will get increased attention during the second decade. This will not mean abandoning the need for continued technological development and scientific research, however.

Article 11 of the 14 article Ministerial Declaration opens by providing some comfort to those who know that the observing systems need to be developed and sustained if any of the data products that the Ministers seek to rely upon are to be available reliably. In that article the Ministers resolved "to sustain and develop the observing systems required to provide high-quality reference data and time-series Earth observations."

With 102 member countries and 92 participating organizations, GEO has grown substantially larger in the 12 years since its creation. It is at least as important to see that it has also grown in breadth, capacity and utility in that time. As is evident from the Mexico City Declaration, GEO and the GEOSS it is working to develop have become important decision-making tools for political leaders and workers in the field alike. How well GEO manages the substantial responsibility that comes with this evolution will depend in part on how well providers and users of data build ever stronger habits of communication and synergy in the years to come.

The next plenary session of GEO is scheduled for Saint Petersburg, Russia in November of this year.

The Mexico City Declaration and other documents from the last plenary and Ministerial Summit are available on the GEO website at https://www.earthobservations.org/geo12.php.

The Tragedy of the Commons

Government Open Data Edition

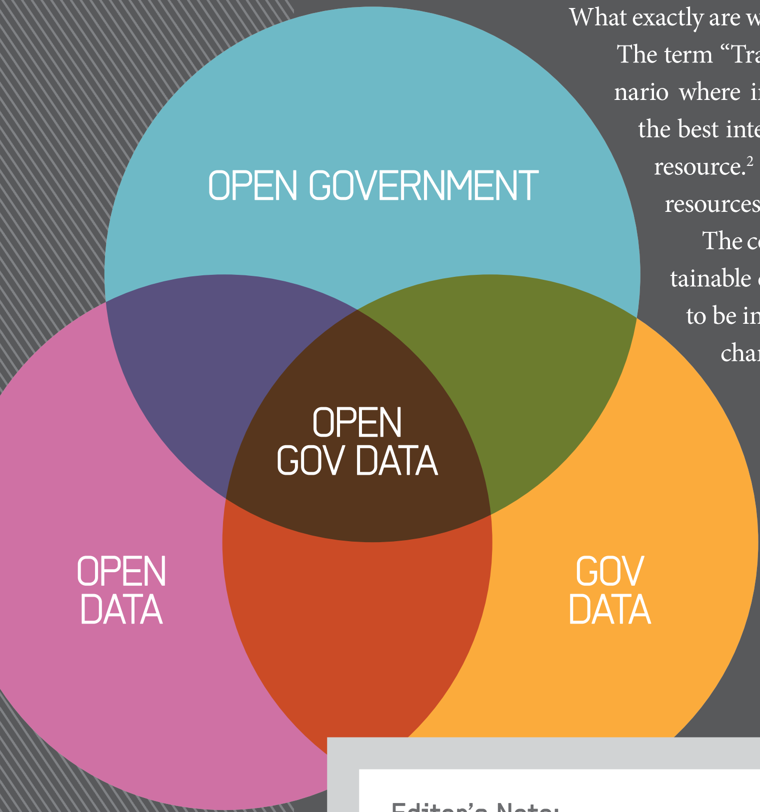
DR. TYRONE GRANDISON / U.S. DEPARTMENT OF COMMERCE
WASHINGTON D.C. / WWW.TYRONEGRANDISON.ORG

IN DATA USE AS IN SEVERAL OTHER AREAS OF THE FEDERAL GOVERNMENT, CITIZENS ARE unaware of the significant investment, financial and otherwise, needed and executed for their benefit and that of the private sector. This is especially true for freely available and open data.

What exactly are we talking about?

The term "Tragedy of the Commons" dates back to the 1830s[1] and refers to the scenario where individuals act (rationally) in their own self-interest and contrary to the best interests of the whole community, by depleting some common or shared resource.[2] In the classical sense, "commons" refers to shared and unregulated resources, such as land, air, oceans, etc.

The concept of the tragedy of the commons is often used in the context of sustainable development, underscoring that to avoid this "tragedy," solutions need to be in place that marry economic growth and resource protection. A lot has changed since 1830 and a lot has remained the same.



WHAT DOES THIS HAVE TO DO WITH GOVERNMENT DATA?

Data is the currency of our time. It is the new "commons" – collected, managed and curated by the government when it is too expensive for the private sector to even contemplate doing so.

The investment in gathering and disseminating data to everyone for free has led to a range of benefits – new businesses, new insight on life, product feedback, and new reference points for better decision-making, to name a few.

Editor's Note:
All opinions are those of the author and do not represent the organization with which he is employed.

Demographic analysis would not be possible without data from the U.S. Census Bureau. The global weather industry would not exist without data from the National Oceanic and Atmospheric Administration (NOAA). Economists and business owners would have no idea about the health of the economy without the data from the Bureau of Economic Analysis.

Of the $9.8 billion requested by the Department of Commerce in its 2016 budget,[3] a significant portion will be spent on the infrastructure, mechanisms and technologies that create this "data commons."

Contrast this to the 2013 economic valuation of (only) the weather enterprise, which was $31 billion,[4] and you get a glimpse into the contribution that the Commerce Department exerts on our economic lives.

The full impact of the department providing this economic and environmental "data commons" is most likely in the hundreds of billions of dollars to the trillions of dollars in income and wealth creation.

Building this "data commons" for trade, investment, economic growth, and economic opportunity (through the department's twelve bureaus) is not an easy task. However, it is one that the government does as a part of its mission of freely providing open data to all its citizens.

Unfortunately, as with most things in life, there are nuances and complications.

THE PRICE OF DATA PRODUCTION

The satellites, radars, surveys and other mechanisms used to produce the data from the Commerce Department's bureaus:

- were once prohibitively expensive for anyone else to attempt doing, and
- are paid for by budget requests to the United States Congress.

The initial expense was rationalized as the cost of sparking innovation. This is no different from investing in the mission to the moon, which was deemed as a necessary step in demonstrating the technical prowess of American science.

The Congressional budget process is an active negotiation that normally leads to the disbursement of less funding than initially requested and than necessary to complete the missions. This leaves a situation where investment costs are high and the allocated budgets are often insufficient to cover the collection and dissemination of the "data commons."

THE LACK OF RE-INVESTMENT

Over time, advances in technology have made it possible to:

- leverage the open data produced by the department's bureaus in realistic timeframes, and
- lower the data production costs.

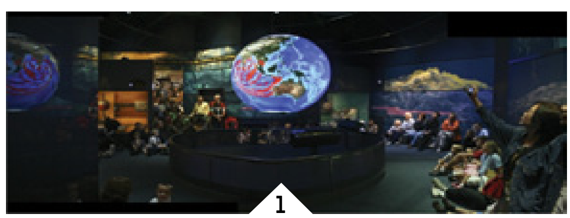
The current crop of multi-billion dollar industries owes its existence to these technological developments. In the process of using these developments, they heavily utilize and capitalize on the department's infrastructure investment.

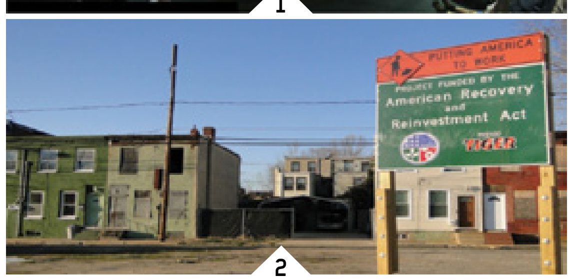
Unfortunately, the current set of advances creates new demands and requires a paradigm shift in terms of native collection and dissemination. If companies contained internal divisions that handled the extract-transform-load (ETL) process, the company executives would re-invest in upgrading the backbone of their businesses to meet these market demands and to stay competitive.

Unfortunately, the same is not true when that backbone is supplied by a government entity. The prevailing perception is that the backbone has already been paid for through taxes.

This perception of the backbone having been "paid for" persists despite the knowledge that budget requests are often made in the context of maintaining existing systems and that these requests are usually significantly reduced by the time the negotiation concludes and monies are allocated.

These facts should be an indication that successful companies should re-invest in the infrastructure that they rely upon to provide them (and the rest of the country) with reliable, free, high-quality, and open data. Unfortunately, this does not appear to be the case.





◀ FIGURE 1. Science On a Sphere at NOAA

◀ FIGURE 2. The Promise of Investment – The Recovery Act

3

▶ FIGURE 3. Corruption Exists Everywhere

FAVORITISM AND COMPETITION

Two golden rules are oft articulated in polite circles:

1. **The government should not play favorites.**
2. **The government should not compete with existing businesses.**

For a myriad of good reasons, there is a web of regulation that encapsulates the notion that federal entities are a resource for everyone and not for a select well-connected few.

Unfortunately, the history of industries that leverage federally produced data is littered with examples of creative alliances that lock vendors in, create effective monopolies and stymie long-term innovation. These partnerships need to be untangled and re-purposed to fully serve the American people.

My favorite phrase to hear from a budding, or even a seasoned, business person is "the government should not be competing with existing companies."

Two things always pop to mind:

The first is incentives. Businesses have no incentive to serve the under-represented; they have no motivation to provide free and open foundational components upon which entrepreneurs can innovate; they have no push to altruistically develop market offerings that will not yield a profit (yet have a market demand). However, the government does. What happens when the government develops data products that provide equal and undifferentiated access to all and in the process (inadvertently) competes with an existing business, as the offering increases in popularity and scope?

The second is value and viability. A few companies capitalize on a market gap created from a deficiency in the government's data production and dissemination process – whether it is in the packaging of the data products or the abstruseness of the end products.

Are we saying that the federal entity is stuck doing things the way that they have always done them? What happens when they receive funds to correct past underfunding and start "doing things in better ways"? Should the current "capitalizing" companies be allowed to force the government to stay in a stagnant state in order to protect the business interests of the companies?

In a capitalist environment, when a company is in a field, sector or niche that advances, that business is expected to innovate and find new revenue streams or face irrelevance. It makes sense that in an environment where a firm's value is in correcting an artificial gap, and that gap is fixed, they should innovate and support the greater good of the larger community.

On the other side of the coin, the cost of instrumentation and data collection has dramatically decreased and businesses see value in competing with the mechanisms of the federal government.[5] These businesses hope to sell their data to the government, increasing the cost of data production and reducing the probability that the general public will have access to free and open data. The possible downstream effects range from mildly annoying to severely catastrophic.

It is instructive that businesses can see the validity and reasonableness in their competing with the government, but not see the validity or reasonableness in the government competing with them. Either there is validity in everyone competing or there is no validity in businesses and the government competing. Both cannot be simultaneously true in the same world.

BRINGING IT ALL TOGETHER

Right now, there are entities that are currently acting in their own self interest and contrary to the needs of the broader community by trying to reduce, and not re-investing in, the shared resource of free and open data. We need to start addressing this tragedy – before it is too late. ∧♂

Endnotes:

1. Lloyd, William Forster (1833). *Two lectures on the checks to population*. England: Oxford University.
2. Hardin, Garrett (1968). "The Tragedy of the Commons". *Science* 162 (3859): 1243–1248. doi:10.1126/science.162.3859.1243. PMID 5699198.
3. DOC OPA (2015). "Fact Sheet: FY 2016 U.S. Department of Commerce Budget": https://www.commerce.gov/news/fact-sheets/2015/02/fact-sheet-fy-2016-us-department-commerce-budget
4. Lazo, Jeffrey (2013). "The Economic Value of the Weather Enterprise": http://www.ametsoc.org/boardpges/cwce/docs/profiles/LazoJeffreyK/2013-04-AWF.pdf
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DISCOVERING Invisible Data

Participatory GIS

BY LINDA DUFFY / PRESIDENT / APROPOS RESEARCH
GOLDEN, COLORADO / WWW.APROPOSRESEARCH.COM

REMOTE SENSING, AERIAL IMAGING, LIDAR and other technologies allow us to map almost every inch of the Earth with unprecedented precision. This approach supports in-depth geospatial analysis based on quantifiable data; however, there is great value in adding qualitative information to the mix.

> **Editor's Note:**
> Several articles on the power of PGIS/VGI have appeared in this publication previously, and can be found at www.apogeospatial.com.

By incorporating factors such as cultural practices, traditional tribal boundaries, and public sentiment into our maps, decision makers can make better choices about resource management, urban development and overall land use. The current trend towards participatory GIS (PGIS) is tapping into the invisible data possessed by people living in communities who previously had difficulty being heard on issues that impacted their quality of life due to their lack of official status and authority.

INVISIBLE DATA

Dr. Melinda Laituri, professor of geography at Colorado State University, discussed the value of collecting invisible data using participatory GIS (PGIS) in her keynote speech at the 2015 GIS in the Rockies conference. Dr. Laituri has worked with indigenous people around the world to create maps that integrate spatial and non-spatial data to provide better tools for decision making, and ultimately help marginalized groups.

"Development projects are driven by community needs and issues," explained Laituri. "In addition to non-crisis mapping to support land use and resource management, the value of accurate maps has been proven repeatedly in emergency response and in rebuilding after natural disasters. But not only do we need an accurate record of roads, population centers, and hospitals; we need to identify cultural practices and other invisible factors that are not normally mapped and include these in the analyses to make the best decisions."

PARTICIPATORY GIS

PGIS is sometimes referred to as collaborative mapping, volunteered geographic information (VGI), or crowdsourced mapping; the basic idea is that members of a community possess knowledge not known by outside parties, and that locals should have the opportunity to create their own maps, or augment existing maps, that include information important to them.

In developed countries, this sharing of information may take place at a mapping party where volunteers get

1

▶ FIGURE 1. Participatory map of subsistence practices, Yukon River Delta, Alaska. Courtesy of M. Laituri.

together to contribute points of interest to a city street map. In developing countries, it more likely involves donations of hardware and software and grants to support teams of researchers who educate local people about the use of geographic information and to help them build maps from scratch. Increasingly, bridges are being built between off-site and local mappers to integrate tools, technologies and spatial information about places that lack geospatial information.

"I've worked with marginal populations around the world who have not been heard and have not been able to map in the past," said Laituri. "The issues being addressed depend on the location. Some people are dealing with climate change that leads to new migration patterns of traditional food sources, or coastal flooding that threatens existing towns and villages, or invasive species pushing out indigenous plants."

APPLICATIONS OF PGIS

Awareness of the value of geographic information provided by volunteers has grown over the past fifteen years following a string of natural disasters, including the devastating earthquake in Gujarat, India, in 2001; the tsunami in Indonesia in 2004; Hurricane Katrina along the U.S. Gulf Coast in 2005; the earthquake in Haiti in 2010; and the outbreak of Ebola in West Africa in 2014.

▲ FIGURE 2. Remote locations increasingly have connectivity through innovative use of technology. This shows a Mongolian household. Courtesy of M. Laituri.

During these events, the Internet made it much easier for volunteers to contribute time and money without actually traveling to the impacted site, while consortiums of international agencies and commercial entities joined forces to make technology and tools available. In some cases where government agencies were overwhelmed, NGOs and private individuals contributed a great deal, such as the "people finders" website created by individuals after Hurricane Katrina, and maps of Haitian refugee camps developed by volunteers on OpenStreetMap. Invisible data also helped prevent the spread of Ebola in West Africa after cultural data about kinship networks and burial practices were analyzed.

Applications of maps created using PGIS include urban planning, infrastructure planning, health studies, irrigation and drainage, social and economic planning, land tenure, and disaster mitigation. "One of the biggest challenges we have with PGIS is to facilitate actions afterward without inflicting our own values or opinions on a community," said Laituri. "We can educate local people about GIS and provide them with satellite images, GPS units and other equipment, but ideally we would like to revisit and make sure that the maps are continuing to address the community issues and successfully empowering the people."

ENVIRONMENTAL PGIS

In North America, community-based mapping got its start in the '90s when university students with access to computers and GIS software worked with grassroots organizations to analyze the impact of activities that could harm the environment, such as mining, drilling and logging. Dr. Renee Sieber, associate professor of geography at McGill University and Chair of GIScience 2016, began her career as a community organizer, during which time she observed the use of maps made by third parties that didn't necessarily reflect the whole truth about actual conditions. To counter the misleading representations, she and her co-workers began making their own maps.

"Back in the 1990's, the technology was difficult to work with," Sieber said. "But I really believed that communities should make their own maps and not wait for someone else who probably didn't have firsthand knowledge of the issues in the area."

"There are really two types of participatory GIS," Sieber continued. "PGIS has more of a community mapping focus, and includes drawing a map in the dirt with a stick, as well as marking points on a contour map on a tablet. PPGIS is public participation GIS, which involves more advanced spatial analysis and commonly takes place throughout North America, rather than in developing countries."

Sieber points to environmental grassroots organizations operating on a shoestring as an example of creating maps without expensive software and hardware, and successfully communicating vital information. "Counter-maps offer a bottom-up perspective from the local people, as opposed to a top-down perspective from government authorities or industrial representatives," Sieber explained. "Counter-maps had a huge impact on legislation related to logging old-growth forests in the Pacific Northwest, with habitat protection for spotted owls being one of the most contentious topics. And in developing countries, community-generated maps have been a valuable tool for indigenous groups to protect their property from exploitation."

WHO IS HELPING?

There are many entities involved with PGIS today. Some NGOs, such as Ecocity Builders, and foundations, such as Secure World Foundation, focus on educating local groups about GIS and how to use the tools available to build healthier urban environments. The Association of American Geographers also participates in research and education projects worldwide to spread knowledge about mapping and its diverse applications, while industry representatives, such as Hewlett Packard and Esri, donate hardware, software and expertise to assist mapping projects.

Regional groups like Kathmandu Living Labs concentrate their efforts on helping their own communities to improve everyday life, as well as responding to natural disasters. As covered in this publication previously, Ushahidi has developed an open source tool for collecting crowdsourced input from multiple sources (smart phones apps, email, Twitter), filtering and managing the data, and creating user-friendly visualizations in the form of maps and charts.

Since being founded in 2006, OpenStreetMap has recruited volunteers on a global scale to contribute to a map of the world that is not subject to licensing fees. The Humanitarian OpenStreetMap Team (HOT) supports the use of open source and open data sharing for humanitarian response and economic development and was active in Nepal after the 2015 earthquake.

SPATIAL AWARENESS IN THE FUTURE

All kinds of information related to location, geography and people is important to support decision making. This realization is driving the development of creative ways to collect and utilize data. Dr. Laituri believes, “PGIS and the increasing availability of online tools and collaborative mapping efforts raise the visibility of not only invisible data, but also spatial thinking and its relevance in everyday life.”

“The future looks very bright for community-based mapping,” said Sieber. “We will see more analytical tools and more projection libraries available on the GeoWeb, and advanced use of social media to create sentiment analysis maps representing community feelings. There will be more MapTime groups that offer tutorials to educate their members about GIS and mapping, and growth in the number of volunteer organizations who are dedicated to mapping the world. There is a lot happening on many fronts.” The magnitude of the full impact will likely exceed our imaginations.

▶ FIGURE 3.
Participatory mapping in the Bale Mountains of Ethiopia using satellite imagery and local experts. Courtesy of M. Laituri.

Data Management & Married or

Galdos Systems Inc., Skyline Software Systems, and Onix Networking Corp.

BY MATTEO LUCCIO / CONTRIBUTOR / PALE BLUE DOT LLC / PORTLAND, ORE.
WWW.PALEBLUEDOT.COM

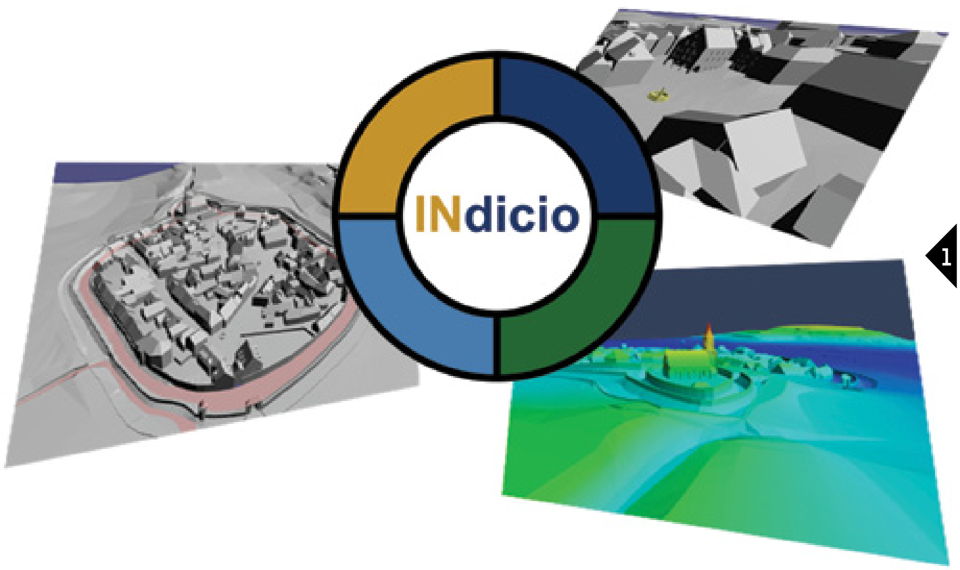
Editor's Note:
The is the 2nd in a series of articles offering companies options and definitions for data management and visualization. The 1st feature in the Fall 2015 issue included VRICON's Globe in 3D, and Esri's ArcGIS Earth (http://bit.ly/1XPOhka).

Also, see article on new OGC standards for "Digital Earth," the Discrete Global Grid System, on page 22.

Large users of geospatial data are searching for alternatives to Google Earth Enterprise (GEE), which Google will discontinue in the spring of 2017. Several geospatial companies offer partial replacements, though their offerings differ somewhat from each other and from GEE.

The first installment in this series in the Fall 2015 issue, "The Demise of Google Earth Enterprise: ArcGIS Earth & Vricon Fill the Gap," covered two of the possible alternatives to GEE. This installment covers three more companies that can provide at least a partial replacement to GEE: Galdos Systems Inc., which makes INdicio; Skyline Software Systems, which makes SkylineGlobe and TerraExplorer; and Onix Networking Corp., which integrates Skyline software into organizations' IT systems.

Visualization: Separated?



▲ FIGURE 1. INdicio can manage and serve large volumes of imagery, digital elevation models, and related content.

GOOGLE EARTH ENTERPRISE

GEE is an on-premise, 3D application that many organizations use behind their firewall to control who has access to their data. It stores and displays huge amounts of imagery, as well as terrain data. One use of the terrain data is to search for line-of-sight paths between locations. For example, companies setting up microwave stations want to make sure that there are no mountains, hills, or buildings between their proposed locations.

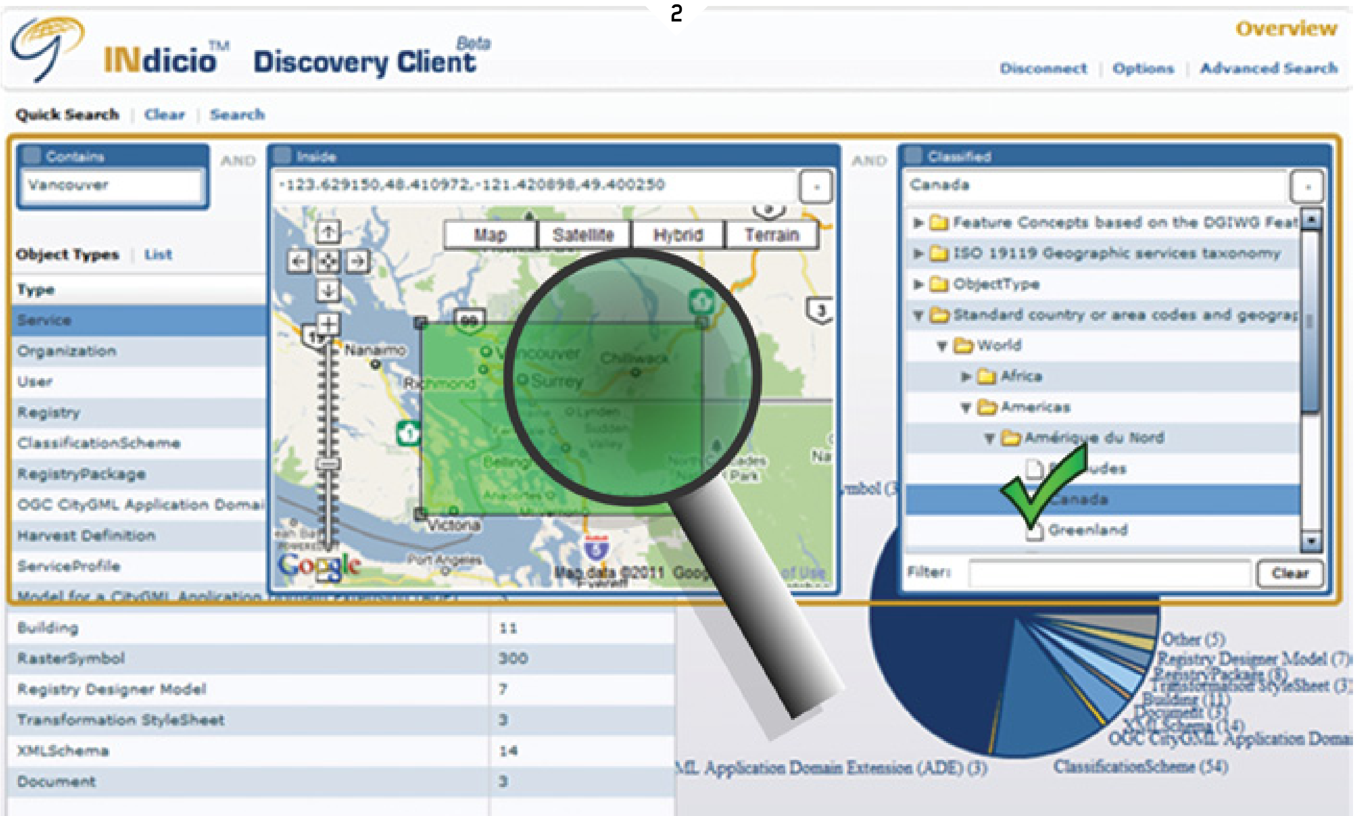
The demise of GEE leaves a big space to fill. "It is an extremely powerful product and it has done a great deal of good for the geospatial community by commoditizing GIS data for actual consumers," says Matt Harrison, vice president of the Defense Business Unit at Skyline Software Systems. Google's discontinuation of the platform, however, is not surprising. "They are focused primarily on the consumer market and on advertising and revenue generation, and the sheer number of GEE users just didn't move the needle for a company that large," says Harrison.

Since Google announced its deprecation of GEE on March 20, 2015, many people who previously only knew the Google brand have been investigating alternatives. "So, we've been educating people on alternative solutions and differences in capability," Harrison says.

GALDOS SYSTEMS INC.

INdicio is a data management system. Any data object stored in it can have many properties, including spatial properties, and it can manage, spatially index, and spatially search for images. "INdicio provides far stronger data management capability than Google Earth does," says Ron Lake, CEO of Galdos Systems Inc., which developed INdicio. For example, he points out, it enables users to describe the semantics of their data.

Often, large organizations need to synchronize data for a wide area, across multiple databases.



▲ FIGURE 2. INdicio can index and manage any type of data and can support complex searches that include spatial and geometric properties.

▲ FIGURE 3. INdicio can synchronize data from multiple disparate sources across a wide network of databases and systems.

For example, a city's GIS may contain such features as roads, fire hydrants, and policing districts, and somebody may want to be alerted whenever a fire hydrant is changed or added, without having to periodically query the database and look for changes. They can do that by subscribing to that data. Some people may want to circumscribe their subscription even further. For example, they may only want to be alerted, in real time, when fire hydrants in a certain neighborhood are modified or added. "People think of that as normal for, say, banking information but maybe less so for information that has geographic properties," Lake points out.

INdicio enables users to automatically synchronize any of their data, including geographic data, with other databases. It has a subscription and publication capability that enables it to automatically subscribe to data as it is changed in any of its various sources and can act as a publisher to automatically distribute data to subscribers across a wide area network. "We believe that data synchronization in these senses should be a capability of an enterprise information system," says Lake.

INdicio can visualize geographic information by overlaying it on a Web map service, but that is not its strongest suit because, unlike GEE, it is not an Earth model with an image base. However, there are other visual globes—such as Cesium and World Wind—that can be used in conjunction with INdicio. "On the other hand, if you are trying to manage a large amount of data that has location and extent and some other properties, and this information is critical to your enterprise, then INdicio can do that," Lake says.

Like GEE, INdicio is capable of managing and serving very large volumes of imagery and digital elevation models. One INdicio user has a database of 40 million objects, such as hotels and points of interest, and requires the ability to update it at about 50 inserts per second per core, says Lake. "We are certainly able to do that. The ability to insert/update data and then query it based on a wide variety of criteria—some of which are spatial, some of which are taxonomic, and some of which are based on relationships with other objects—is a strong suit of INdicio and much stronger than in the case of Google Earth," he says.

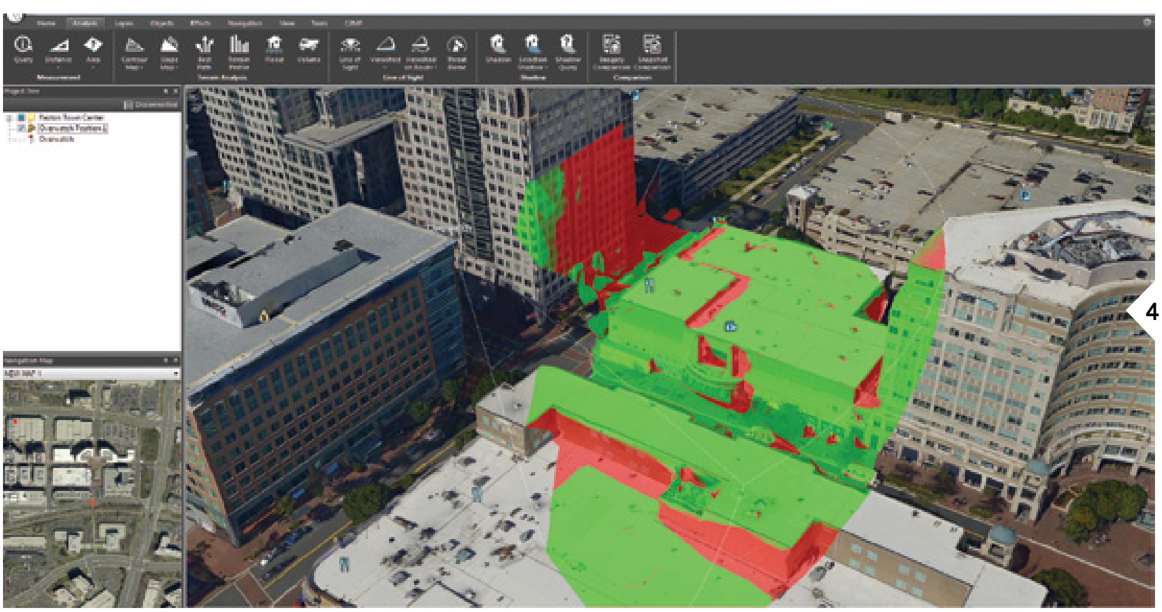
SKYLINE SOFTWARE SYSTEMS

Skyline Software Systems, which does the vast majority of its U.S. business in the military and intelligence community, can provide an alternative to GEE as an enterprise system. "Our target customers are those people who want to build up, present, and disseminate their own information out to a community of users—be they military operators or state and local governments trying to get results out to the populace," says Harrison. "We sell them the architecture to stand up their own data, customize the front end, and then disseminate that data out to users."

One big differentiator between Skyline and GEE is the former's ability to read data natively. Using GEE requires organizations to re-process all of their data into Google's terrain database through Google's engines or through a third-party architecture. Furthermore, any vector or image overlay has to be in KLM or KMZ format. Skyline, Harrison explains, reads any kind of raster imagery or vector data in its native format, from its native location, with virtually no re-processing. "We are able to dynamically render it in 3D, in real time, so you don't have to spend days, weeks, or months re-processing your data to get it into our format," he says.

Another differentiator is the ability to disseminate out capabilities to end users. "Google Earth is a fantastic viewer, but that is pretty much the extent of it," says Harrison. "Very little analysis actually occurs at that end. Our end user, using just a free viewer, can do terrain analysis, line of sight, slope mapping, contour mapping, view sheds, and much more."

Skyline's client software, TerraExplorer, is very comparable to the Google Earth Pro client. It has three tiers (the Viewer, the Plus, and the Pro), which scale up capabilities. Its server software, Skyline Globe, is analogous to Google Earth Fusion and the Google Earth server. However, Harrison points out, while GEE's architecture is rated for 250 concurrent users, Skyline's Globe architecture is rated for 1,000 concurrent users.



◀ FIGURE 4. 3D Viewshed displayed in TerraExplorer, a product of Skyline Software Systems. Models supplied by Fugro.

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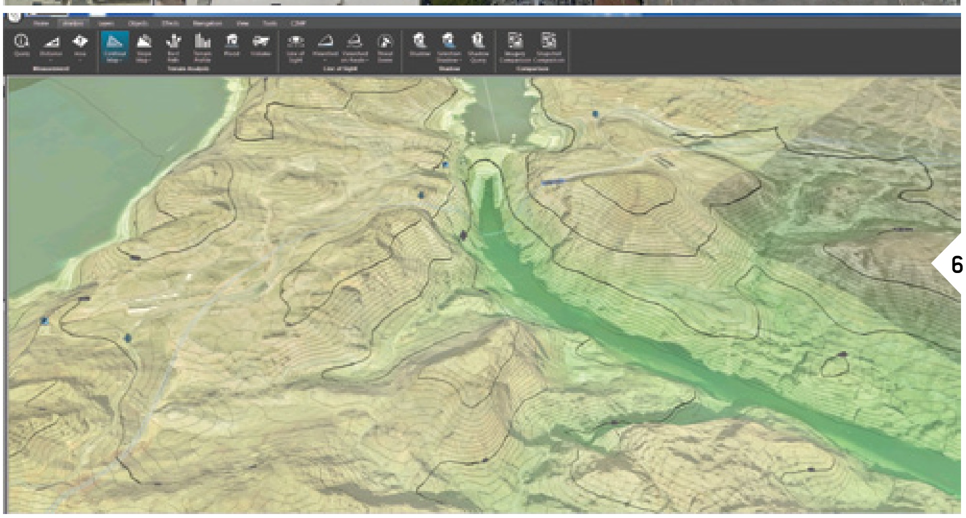

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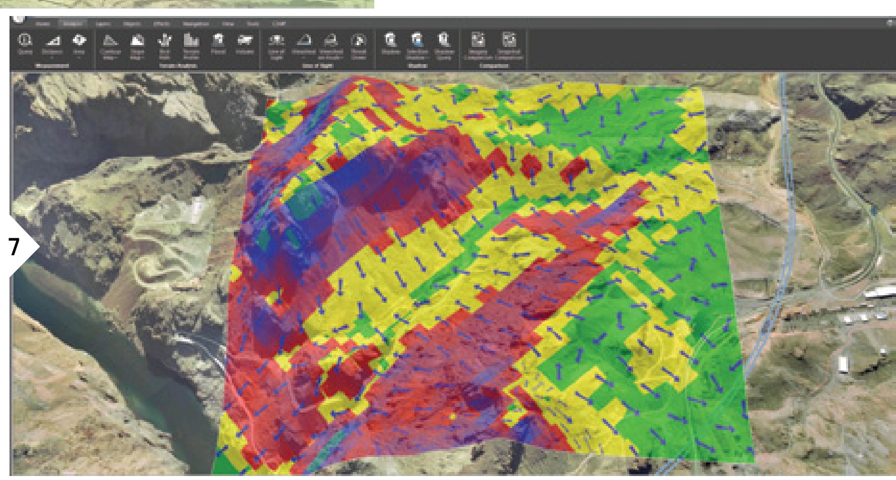


▲ FIGURE 5. 3D Viewshed Query displayed in TerraExplorer. Models supplied by Fugro.

▲ FIGURE 6. Elevation Contour Map displayed in TerraExplorer.

▶ FIGURE 7. Intensity and direction of terrain slope displayed in TerraExplorer.

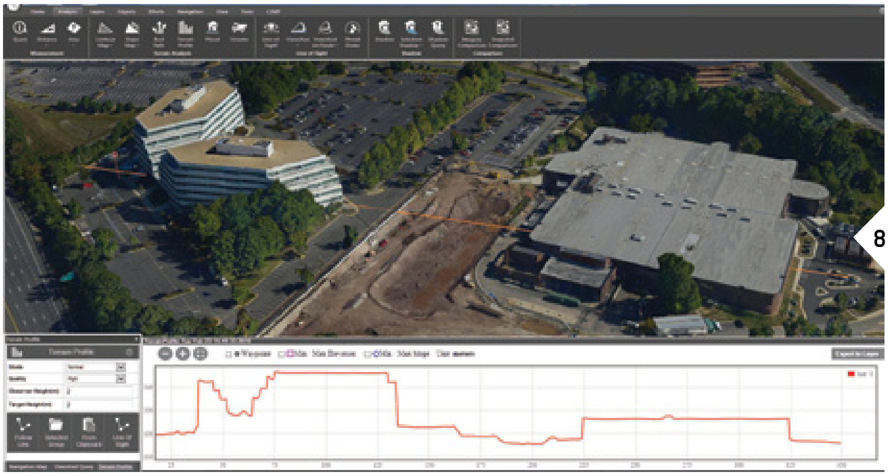
ONIX NETWORKING CORP.

Onix Networking Corp., an IT infrastructure company, is one of the largest integrators of Google software. It is a sales organization but also has an engineering and support back end, explains Dal VanDervort, the company's vice president for public sector sales. Onix can help organizations that have been using GEE for years to migrate their data to Skyline, intergrate Skyline into their networks and infrastructures, conduct trainings, and provide technical support.

A downside of the imagery available via GEE is that it is proprietary and has to go through Google's fusion server, points out VanDervort. "So, one of the things that we bring to large organizations is a variety of different types of imagery that they can load through the fusion server, which is very popular."

When Onix began looking for a replacement for GEE, they were looking for a 3D platform that offered terrain data and would allow measurements to be taken on screen while looking at imagery. "Nobody out there had a promising 3D imaging application, not even Esri," says VanDervort. Then Onix found Skyline, which has a true 3D application, as well as terrain data capabilities, and measurement capabilities.

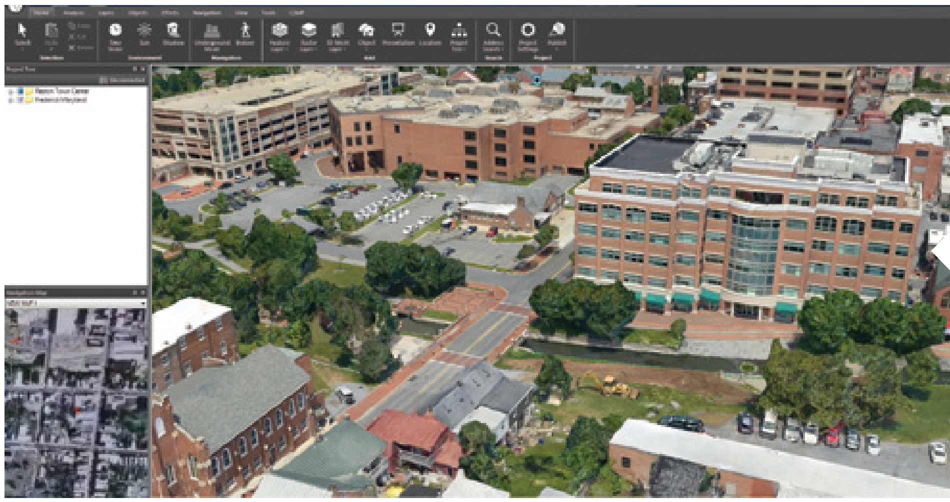
A big piece of Onix' customer base is in the federal government, in particular in defense and intelligence. "A lot of the data that they are using, obviously, has to be locked down," says VanDervort. "So, there are specific items that have to be met in order to keep customers happy as far as moving off of GEE." Because security is a big concern for many of them, their customers need an application that they can host on-premises or build within their network, behind their firewall. It must also have a 3D capability, a measurement capability, and options available as far as the types of imagery that it can use, whether it be lidar, GeoTIFFs,



Commercial applications include route mapping and tracking shipments from manufacturing facilities to store locations. Insurance companies use imagery and geospatial technologies to assess risk at facilities on the basis of their distance from fire houses and hospitals. “The use cases for these types of solutions just continue to grow year over year over year,” says VanDervort.

◀ **FIGURE 8.** Profile of Terrain displayed in TerraExplorer. Models supplied by Fugro.

▼ **FIGURE 9.** 3D Models displayed in TerraExplorer. Models and Imagery provided by Icaros.



or other formats. Skyline offers all of those capabilities.

Another key capability is APIs for development. “Every application out there needs an API or a development piece for their solutions,” say VanDervort. Yet another very important consideration is the number of concurrent users that a platform can handle from a wide variety of mobile devices. “Most of our customers are global and want to be able to use their data from wherever they are, using a tablet or a phone or something else,” says VanDervort. Skyline, he says, meets all of those criteria as well.

A good example of an organization looking at a product like Skyline, says VanDervort, would be an oil and gas company looking at placing new pipelines. It needs to know what the terrains look like. “If they are trying to maintain existing lines, they could use up-to-the-minute fly-by data or imagery and push that through Skyline 3D to map existing piping systems, electrical lines, or phone lines,” he explains. “There’s a lot of data that you can put in there to show rights of way or county lines, possibly vegetation and growth restrictions, where you have to go in and make some changes.”

Another good example is airports. “Many airports use a 3D imaging solution for runway maintenance, so that they can see whether there are any trees that are overgrowing any areas or if there is anything in the pathway that shouldn’t be.”

IS SPATIAL SPECIAL?

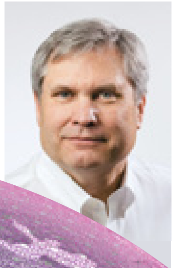
Is spatial data special? It’s an old debate. “It is in the sense that you typically need special data presentation mechanisms and tools, but otherwise it is not,” says Lake. Therefore, unless all of your data consists only of geographic features—for example, if you are a mapping agency—the notion of enterprise GIS is “a wrong notion,” he argues. Most organizations would like a single source of truth for all of their enterprise data, but not all of it has location or spatial extent associated with it.

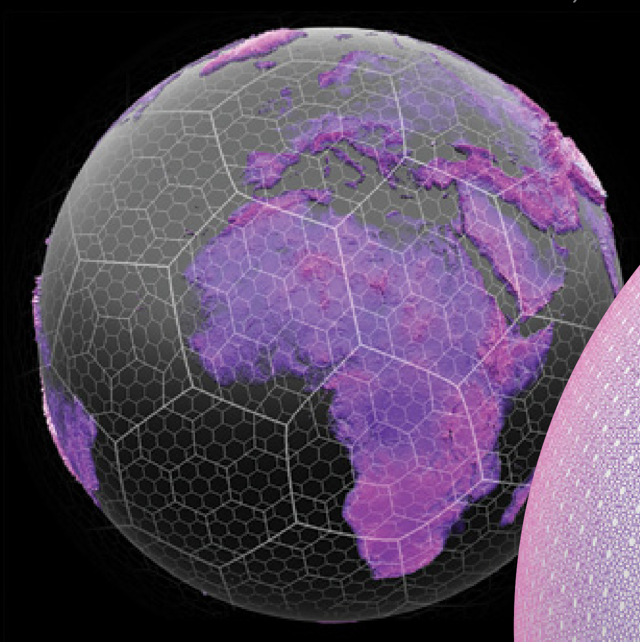
What will large organizations, such as the National Geospatial-Intelligence Agency (NGA), do to replace their reliance on GEE? “I would hope that they would separate data management from visualization, because to me they are different,” says Lake. Separating data management and presentation would make it easier in the future to use different kinds of visual presentation, he argues. ∧σ

Bring It All Down to Earth with DGGS

The New OGC Discrete Global Grid System Standard

BY PERRY PETERSON / PRESIDENT/CEO
CALGARY, ALBERTA, CANADA / WWW.PYXISGLOBE.COM
PYXIS, MEMBER OF OPEN GEOSPATIAL CONSORTIUM





▲ FIGURE 1.
ISEA Hexagonal Discrete Global Grid System

HUMANITY'S ABILITY TO MEASURE, MONITOR, AND COMMUNICATE over the vastness of the entire Earth is unprecedented. Satellites swarm the Earth observing and measuring the events below. A web of sensors monitors and controls changes and movement of a billion things each second. Silos of important content that describe places and their features grow and grow within millions of organizations.

Trends point to ever-growing volumes of rich data describing the planet. People, from scientists to citizens, expect this information in a form that can answer their pressing questions…instantly. At the same time, we are experiencing the rapid unprecedented consequences of environmental changes. It is hoped that the data and information describing these changes can be transformed into the knowledge and decisions that will mitigate the cost. However, promised societal benefits and the commercialized value are difficult to realize.

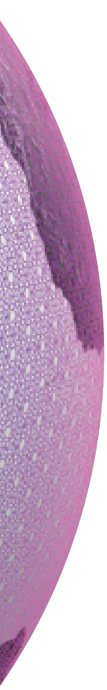
Nowhere are these changes more evident than in the Arctic. The singularity of a pole in a region of vying national interests, traditional peoples, climate change, resource extraction, emerging shipping routes, and a suffering ecosystem have given the Arctic new attention. However, access to Arctic geospatial data has long been a challenge. Remoteness and equatorial fixated map projections have made it difficult to include polar data in the normal offerings of scientific and consumer mapping products.

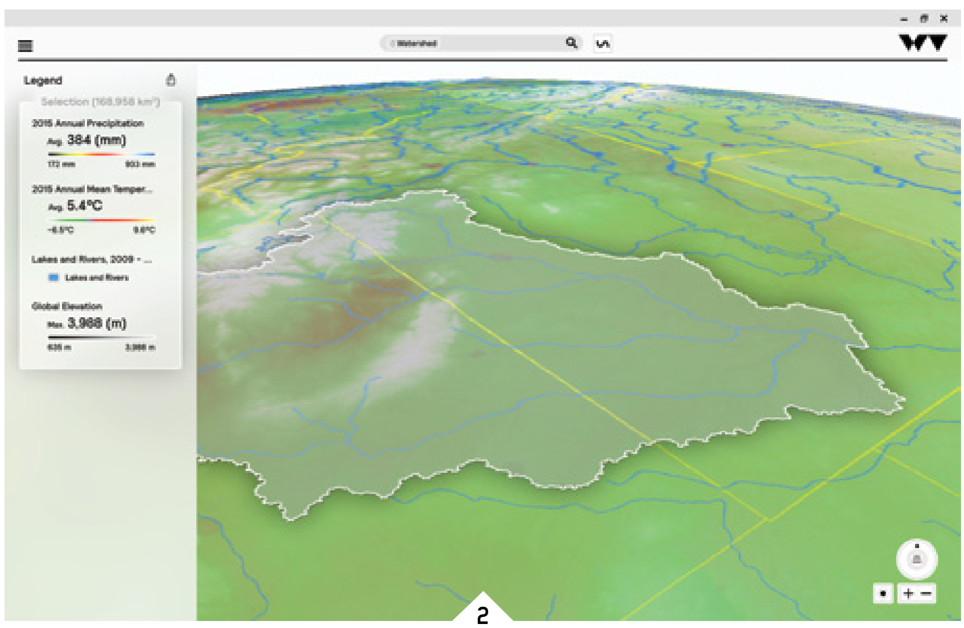
The Open Geospatial Consortium (OGC) will release a candidate for a new Earth reference standard that promises to solve these challenges. It is formally called a Discrete Global Grid System (DGGS). Although DGGS may be new to some, its formal development began in the 1980s with the promising value of global analysis coinciding with the increased use of geographic information systems (GIS) and availability of global data and positioning systems. OGC defines a DGGS as "a spatial reference system that uses a hierarchical tessellation of cells to partition and address the globe. DGGS are characterized by the properties of their cell structure, geo-encoding, quantization strategy and associated mathematical functions."

The difference between conventional geographic coordinate systems and a discrete global grid system is analogous to any "digital" discrete information system. Using points of latitude and longitude to describe information on a continuous geographic surface is an analog model. It is like the continuous analog wave of sound produced by a vinyl record. However, to efficiently put that signal of music into a computer it has to become digital – broken into tiny discrete pieces with values assigned to each piece to reproduce the fidelity of the original sound.

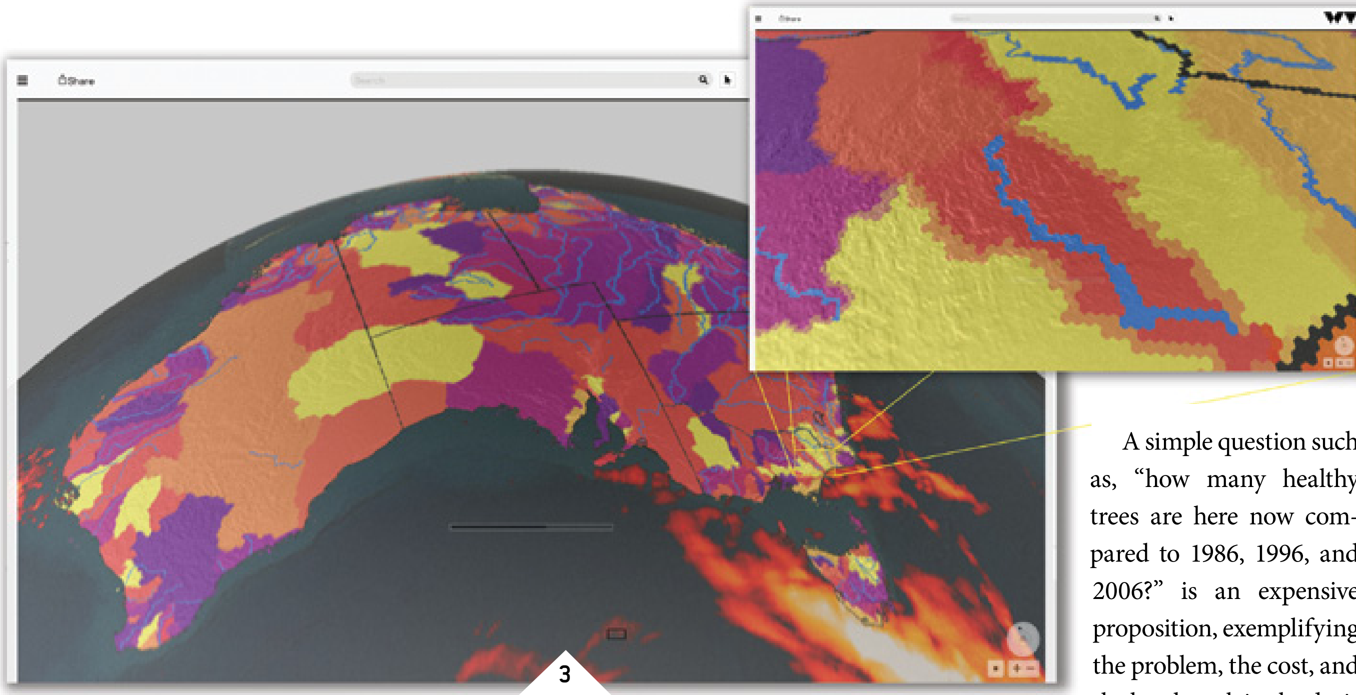
A DGGS is a Digital Earth reference model. The DGGS uses equal area cells to partition and address the entire globe. Digital Earth is not continuous. Each tiny cell – they can be infinitesimally small – has a unique address. Spatial resolution is explicit as every item of information in a DGGS is associated with an area. Geospatial data values from any source, type, format, spatial reference, spatial scale, or frequency can be held in a DGGS cell. The hierarchy of cells provide rapid aggregation and decomposition of data values.

A DGGS is designed to be an information grid, not a navigation grid. Simply put, the DGGS is like a spreadsheet of tiny cells that cover the Earth. Information stored in each cell can record the condition and events describing that place. The idea of a standard means that everyone will use the same fixed cells to record everything from precise scientific observations to crowd-sourced events; a dynamic understanding of where one





▼ FIGURE 2. The Yellowstone River Basin is shown here for watershed analysis, delineated and assessed using elevation, satellite, and other static and real-time data without the need for a GIS intermediary, in the WorldView Studio DGGS.



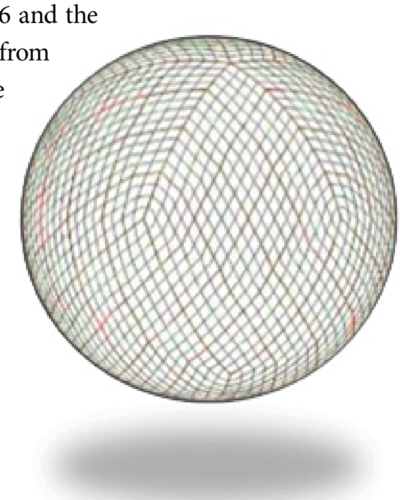
▲ FIGURE 3.
Tiny cells of the ISEA DGGS hold data from vector maps and raster imagery of Australia.

can find certain conditions and what is happening at the place of the user's choosing becomes a simple task.

As a global spatial reference system, polar data in a DGGS is accurately portrayed and equally integrated with map information anywhere else in the world. The DGGS has many other features that exemplify the power of a Digital Earth as well. A DGGS allows multiple data sources to be integrated and analyzed in one workflow without the need to convert or change spatial reference systems. With the trend to more open on-demand systems, DGGS provides a user-centric approach where end users can search for and explore interesting phenomena from multiple content providers simultaneously.

A simple question such as, "how many healthy trees are here now compared to 1986, 1996, and 2006?" is an expensive proposition, exemplifying the problem, the cost, and the bottleneck in the decision-making cycle. The primary challenge is pinning down what is meant by the term "here." If one stands at the corner of the forest and asks how many trees are "here," we might respond that there are no trees, for at the point under our feet there are none, or that there are the 40 we can see from where we stand, or it could be the entire inventory of trees within the ever-changing outline of the forest's edges, or it could mean "here" is a reproducible connection of points defining the forest boundary in 1986. And this is the unfortunate bottleneck. What a human means by "here" can become an expensive, time consuming, and complex process of creating and maintaining a vector map for every feature or phenomena we want to understand.

With a DGGS, that changes completely. Data collected on trees can be recorded with whatever means is available. Estimates in 1986, a rough survey in 1996, a more precise map in 2006 and the almost daily count of trees from a satellite in 2016 can all be used to populate values in the DGGS cells. The decision makers in 2016 select what they mean by "here is the forest." And the aggregation of cell values provides an instant best answer possible given the state of the raw data. Integration of content is on-demand and the once



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Real World Example 1

If you are interested in profitably exploiting radiation from the sun, there are opportunities to use solar heating, solar photovoltaics, solar thermal electricity, solar architecture or artificial photosynthesis, if you can understand the constraints. From remote sensing sources you will need historic measurements of solar radiation. From the regional authorities you will need cadastral property plans and the location of transportation and electrical transmission routes. You will need to know where the consumers of the power are located. You will want to avoid protected areas but access to land is vital. Property plans and land ownership, regulatory areas, existing developments, existing water courses and terrain are all important, too. All of these sources of information are geospatial; they represent something happening "here" – a place or places on a map.

Real World Example 2

A drought has hit a large area of the Amazonian rainforest. It's the third drought in the last 10 years. NASA scientists want to determine its effect on the planet. The loss of trees means less carbon coming out of the air and the decaying vegetation means more carbon being replenished. The scientists must combine many years of data to define the meaning of a normal amount of rain over this area of the globe. Although there is a lot of data available in various forms, integrating all the data is a hard problem. Measurements must align with each other or the comparison is not useful. The overall health of the vegetation is determined in a similar comparison. Finally, the type of vegetation present in the forests is classified. Now the amount of carbon released into the atmosphere can be determined. With conventional methods, this actual study took several months to complete. With a DGGS, it takes about two days. The difference is the efficiency of data integration. When all these pieces of information are integrated together, the decision maker can ask, "Where is the drought severe? What was the result of the drought?"

expensive operation is virtually free.

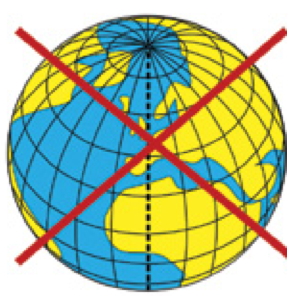
This approach to maintaining the meaning of "here" permits easy repeatable manipulation, visualization and analysis of measurements from any location at any scale. "Big Earth Data" aligned to the digital cells of a DGGS is easy to access, store, sort, process, transmit, integrate, visualize, analyze and model. Producing insightful answers to pressing unanticipated questions, such as "what is here?" and "where is it?" are simple set theory operations.

The world of DGGS assumes multiple sources of content that need to be assembled quickly. See the sidebars for real world examples.

The growth of the Web as a primary source of information dissemination has naturally led to the evaluation of different approaches to efficient Web-based mapping and spatial analysis. The requirement for very fast display of global maps on the Web led Google to adopt a simplified approach to digital mapping. In 2005, Google Maps was released using Web Mercator – a spherical variant of the Mercator projection suitable for partitioning and indexing map tiles for rapid transmission and display. Despite its controversial problems, Web Mercator has become the de facto standard for fast Webmaps.

3D virtual globes provide a spectacular visual navigation of pre-integrated imagery over the planet and represent Version 1.0 interface for a whole Earth information system. Al Gore, in his 1992 book "Earth in the Balance" and his 1998 speech on the topic, introduced Digital Earth. His idea was not merely of a 3D virtual globe to navigate and explore, but a vision for a participatory information system so simple and powerful that children could effectively understand complex facts and events that define the condition and history of our planet.

The new OGC DGGS standard will provide the basis for adopting this new Digital Earth approach to geospatial



◀ FIGURE 4. ISEA Triangular DGGS; cells are equal area, like pixels on a computer screen.

◀ FIGURE 5. Rectilinear SCENZ-Grid

◀ FIGURE 6. ISEA Hexagonal Grid

▼ FIGURE 7. Quaternary Triangular Mesh (courtesy of Geoffrey Dutton)

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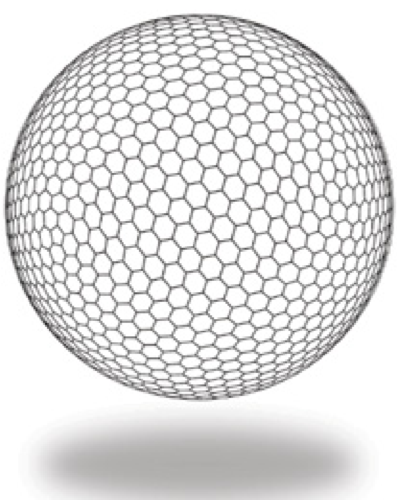

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Real World Example 3

There is an unusual storm front forming over the mountains. A river flows through a city not far from the mountain streams that enter the river. What will happen here is a question people want answered, and fast! Satellite sensors and ground-based measurements provide clues of high rainfall intensity and duration, flow in the streams, land classification, wind, and soil conditions. Terrain models allow for the delineation of the catchment area and flood models. A historically large flash flood is expected within the next 12 hours. Warnings are sent to media with an outline of the potential flood areas. As the flood rises, land use maps are integrated with radar imagery to confirm the population affected by the flood. Twitter feeds begin to include requests for help. First responders implement their mobile command and control systems. Citizen responders want to help with machines and supplies. Many people are asking, "Where are the places where we can make a difference?"

As the flood waters recede, the damage appears formidable. With all the pieces of information integrated together the decision maker can ask, "What has happened here?" Lives of people have changed forever. Supply chains disrupted. Local, regional and national governments respond along with private insurance companies to assess and categorize damages. Helping people with food and shelter is a priority. Rebuilding infrastructure may take billions of dollars. Learning lessons can assist policy making and future planning priorities. All of these sources of information are geospatial. They represent something happening "here" – a place or places on a map.

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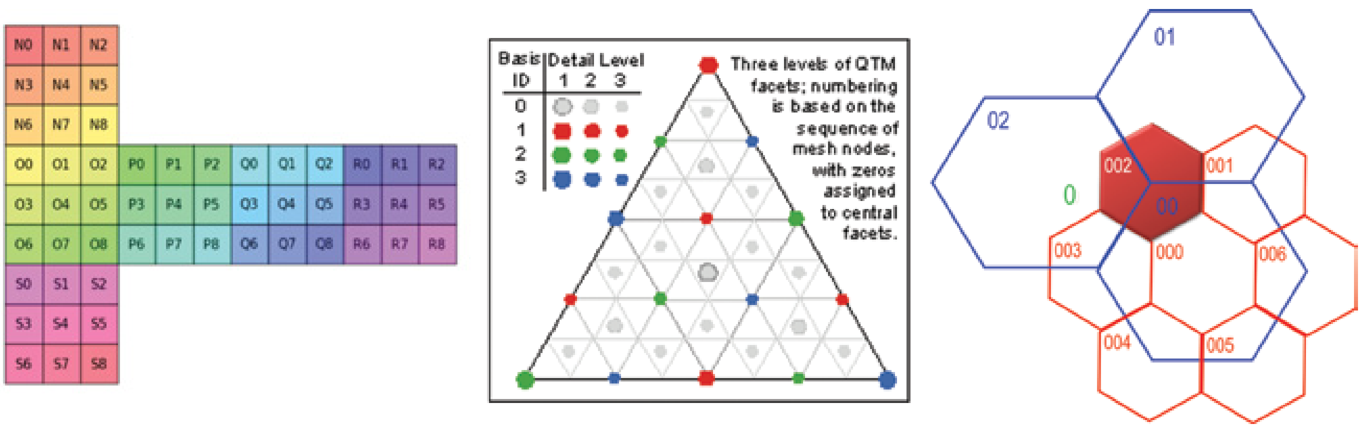


▲ **FIGURE 8.** Like a cell in a spreadsheet that covers the Earth, each cell of a DGGS is given a unique address to facilitate efficient mathematical operations.

decision making. A DGGS is fast, scientifically accurate everywhere on the planet, and allows distributed sources of information to be integrated by the decision maker on-demand. A recent survey of DGGS indicated that there are at least 10 DGGS in active development and use.

SCENZ-Grid DGGS, developed by Landcare Research New Zealand, is a rectangular DGGS designed for use in high performance computing and cloud architectures for inter-disciplinary environmental modeling.

The Web Globe company PYXIS has developed DGGS technologies in collaboration with the Canadian and U.S. Governments. PYXIS Studio uses a hexagonal DGGS for Web-based content discovery, visualization, and analysis. Their rapid search, discovery, and fusion of geospatial content across multiple data jurisdictions has been successfully demonstrated in several OGC testbeds and Global Earth Observation System of Systems pilot projects.

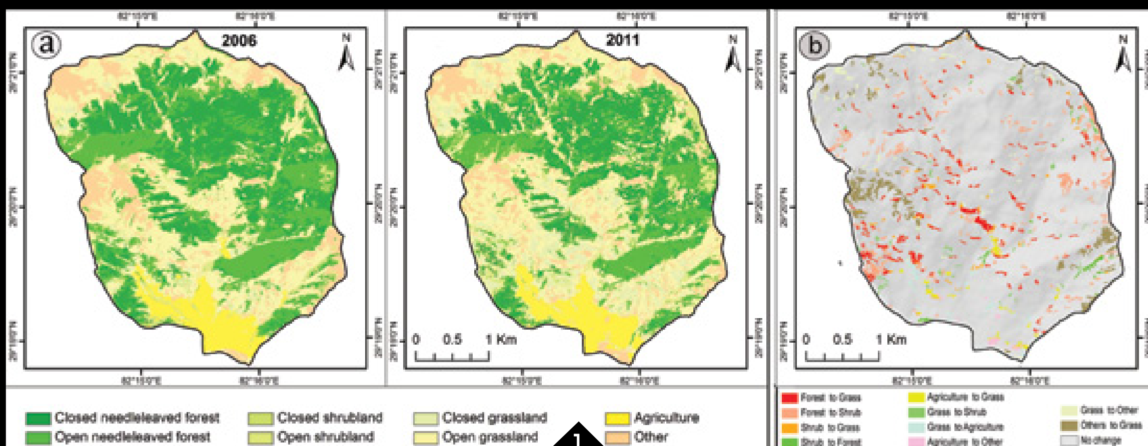
The Royal Canadian Geographic Society is distributing PYXIS WorldView to teachers where it is being used in classrooms to teach GeoLiteracy to children as young as 10 (https://vimeo.com/117639516). Users can also create and share their own globes – a feature that allows anyone to replace static Webmaps with embeddable smarter globes. You can access PYXIS Studio for free at www.pyxisglobe.com. ∧♂

> "The idea of a standard means that everyone will use the same fixed cells to record everything from precise scientific observations to crowdsourced events."

A Crowning Achievement

Measuring Nepalese Deforestation

BY CHRISTIAN HOFFMAN / MARKETING MANAGER / PHOTOGRAMMETRY AND REMOTE SENSING SOLUTIONS / TRIMBLE / BIBERACH, GERMANY / WWW.ECOGNITION.COM



◀ FIGURE 1. Map of the Lorpa watershed showing land cover in 2006, 2011, and change detected. Based on eCognition's analysis, the area lost 12% tree canopy.

On the next page, maps of Jumla and the location of the Lorpa watershed are shown.

For decades, the high-mountain regions of Nepal have been caught in a perpetual catch-22. The small populations of these remote, isolated areas depend nearly exclusively on local natural resources for their livelihoods, yet they have to exploit those same resources in order to have roofs over their heads, heat their homes, cook their food and carve out livelihoods.

In the remote mountainous region of Jumla, for example, around 90 percent of farmers subsist on agriculture production, but their landholdings are typically less than 2 hectares (5 acres) in size, making it difficult to produce enough food and provide enough area on which livestock can graze. So often, they allow their livestock to encroach on the vegetation and they collect firewood, herbs and other ecosystem goods to augment their income and food resources. It's a land-to-mouth existence that has resulted in livestock overgrazing, overusing water and felling trees.

Compounding the situation, major changes in climate have reduced water availability, increased temperatures and produced a shift in growing seasons – all of which impact agricultural production, and further drive people to draw from the environment for goods and services.

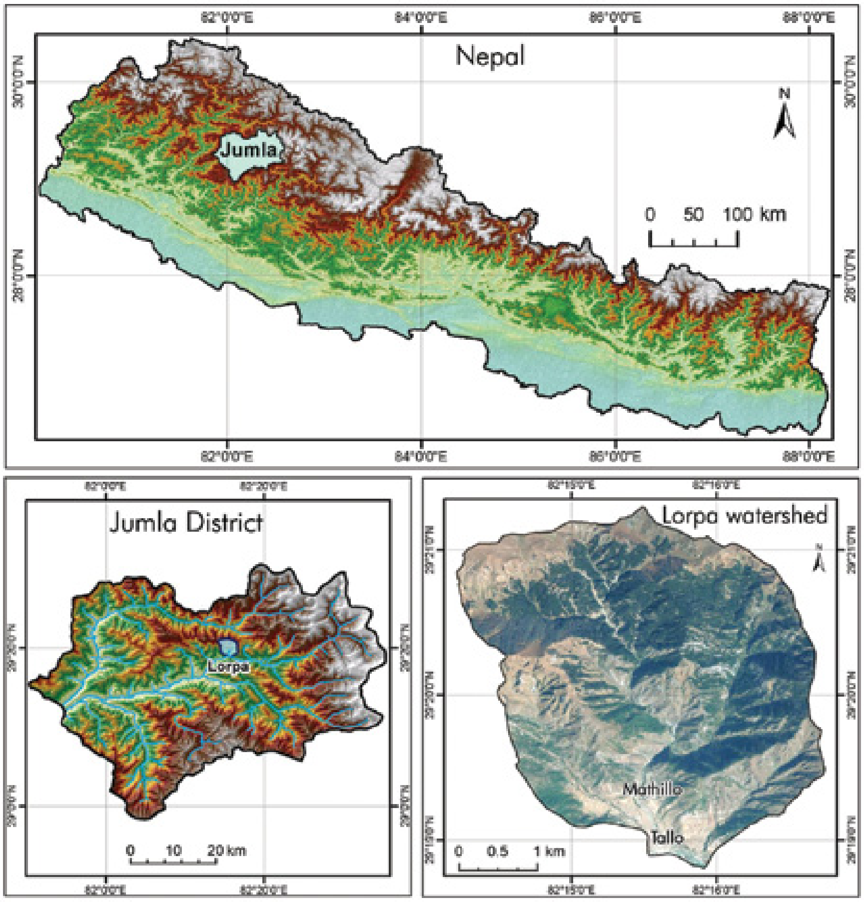
Although this catch-22 hasn't gone unnoticed by the government of Nepal, the geographic isolation of Jumla and other remote areas have made it difficult for authorities to see just how inextricably linked agricultural practices and environment deterioration have become. And that's presented authorities with their own dilemma: how do they develop initiatives to improve and sustain agribusiness as well as strengthen the resilience of the natural resource environment when they don't have a clear picture of the environment itself?

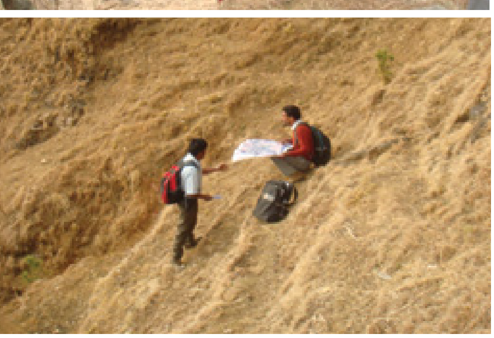
To resolve that challenge, the Ministry of Agriculture and Cooperatives (MoAC) has launched a number of studies focused on high-mountain regions to help gather the intelligence needed to plan smart strategies for economic development. One such study targeted the Jumla region, which aimed to help strengthen agribusiness in the region through more effective management of the local watershed.

However, with the geographic remoteness and isolation of Jumla, using traditional survey techniques to collect the local land cover detail needed would be costly and time intensive. So project managers used geospatial technology to bring the remote view of the vegetation to their desktops. Using a combination of satellite imagery and advanced land-classification technology, they not only produced two land-cover

Editor's Note:

Nepal experienced two devastating earthquakes in April 2015, which were covered in this publication, and Trimble's contributions to the response effort were covered here: http://bit.ly/1WK1Hgw





maps showing Jumla's vegetation changes over time, they provided the visual truth to debunk some long-held, local beliefs that Jumla's forests were not being lost to deforestation.

THE LIE OF THE LAND

A roughly 20-hour drive from Kathmandu, Jumla is a mountain district located in the midwestern region of Nepal. It is comprised of 30 small villages with a total population of just over 101,000 (as of 2011), the vast majority of whom depend on agriculture for their livelihood. Considered to be the birthplace of the Nepali language, Jumla is known for its biodiversity and spectacular scenery, as well as its lack of development; a 2012 National Population and Housing Census ranked it 68th out of 75 districts. And according to a United Nations Field Office report, 99 percent of households use firewood for cooking and up to one-third live below the national poverty line.

Intent on improving Jumla's plight, MoAC in 2010 launched the three-year High Mountain Agribusiness and Livelihood Improvement (HIMALI) project. HIMALI's goals were to enhance the communities' socio-ecological resilience to climate change and to help design effective local watershed management plans to ensure the sustainability of agribusiness in the region. The project specifically targeted two watersheds, one of which was the Lorpa watershed, as representative areas of the district.

The responsibility of collecting the needed intelligence and identifying solutions fell to Kathmandu's International Centre for Integrated Mountain Development (ICIMOD), a regional knowledge centre working to improve living standards and to sustain vital ecosystem services for the eight countries of the Hindu Kush Himalayas.

In order for ICIMOD to identify and recommend solutions, it needed to better understand not only what the present lie of the land in Lorpa looked like, but how its land cover had changed over time – specifically the forests. But given its geographic isolation, acquiring that picture with traditional, physical surveys would not be feasible. So HIMALI became the test case for a new approach to producing land-cover and change-detection maps in remote mountain valleys.

"Forests play an essential role in the health of mountain ecosystems so they are an essential element in devising development plans," says Kabir Uddin, a GIS and Remote Sensing Analyst with ICIMOD. "We needed to inventory the forest cover down to the tree-crown level and map that over time – detail we couldn't possibly gather with traditional surveys. The most cost-effective and accurate way to acquire this information was with satellite imagery and object-based image analysis (OBIA) software."

Having used Trimble's eCognition® OBIA technology since 2006 for a number of land-cover mapping projects in Nepal, Bhutan, Bangladesh and Pakistan, Uddin and his team chose the image analysis and land classification software to create accurate land-classification maps for the Lorpa watershed, which comprises large areas of forest, a lower valley favored by agricultural activity, an intermediary zone and a high-mountain zone dominated by dramatic changes in vegetation.

"Producing land-cover maps for mountainous areas can be challenging for traditional land-classification technologies because slopes, sun and satellite angles strongly affect spectral measurements," says Uddin. "The advanced OBIA technology gives us the tools to overcome these unique challenges and map these regions with high accuracy."

COUNTING CROWNS

The original plan was to map the watershed over a 10-year period; however, acquiring cloud-free or snow-free optical satellite imagery of the region proved most difficult. So Uddin's team had to settle for a five-year interval instead.

Uddin first defined the landscape characteristics of the 5-square-mile (13-square-kilometer) watershed area—typical tree cover, slope angles, proximities to urban areas—and then spent about two months compiling and preparing the core datasets.

They acquired one 2006 QuickBird satellite image and one Ikonos image from 2011 for the change-detection land-cover maps. They also obtained a digital elevation model (DEM) from the shuttle radar topography mission (SRTM) for topographic detail as well as vector data such as buildings, roads and contours. As QuickBird and Ikonos have different resolutions, Uddin had to integrate the ancillary data with each orthorectified satellite scene to create two separate eCognition rule sets, the if-then processing trees that the software follows to determine specific vegetative types.

After pre-processing and validating the quality of the raster data, the data-processing team used Esri's ArcGIS to calculate multiple indexes to help separate vegetation from non-vegetation areas – detail that would be integrated into the classification process.

Then they began writing the customized rules to instruct the software to distinguish vegetation from other object types, and specifically to delineate trees down to the individual crown level. Uddin's team built two eCognition rule sets to distinguish and map 10 land-cover classes including built-up areas, open grassland, agricultural land, open shrub, open needle-leaved forest (more than 40 percent tree canopy) and closed needle-leaved forest (less than 40 percent canopy). Specific to the forest-cover classes, the software also automatically delineated individual tree crowns into five size categories. Once the rule sets were complete, it only took the software 30 minutes to run the workflows and produce land cover maps for 2006 and 2011 showing the change in Lorpa's vegetation between those two years.

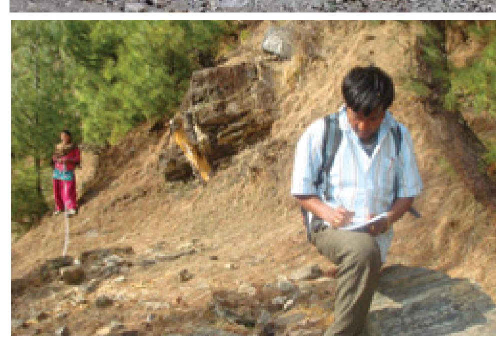
According to the maps, the Lorpa watershed went from a total of 47,121 tree crowns in 2006 to 41,689 in 2011, amounting to a reduction of 5,432 trees or a loss of 12 percent tree canopy. That equates to a loss of approximately 90 trees per month, the majority of which are those with the largest crown areas of 1,076 sq feet (100 sq m). The most significant reductions were in the southwestern part of the watershed where Lorpa's two communities are located.

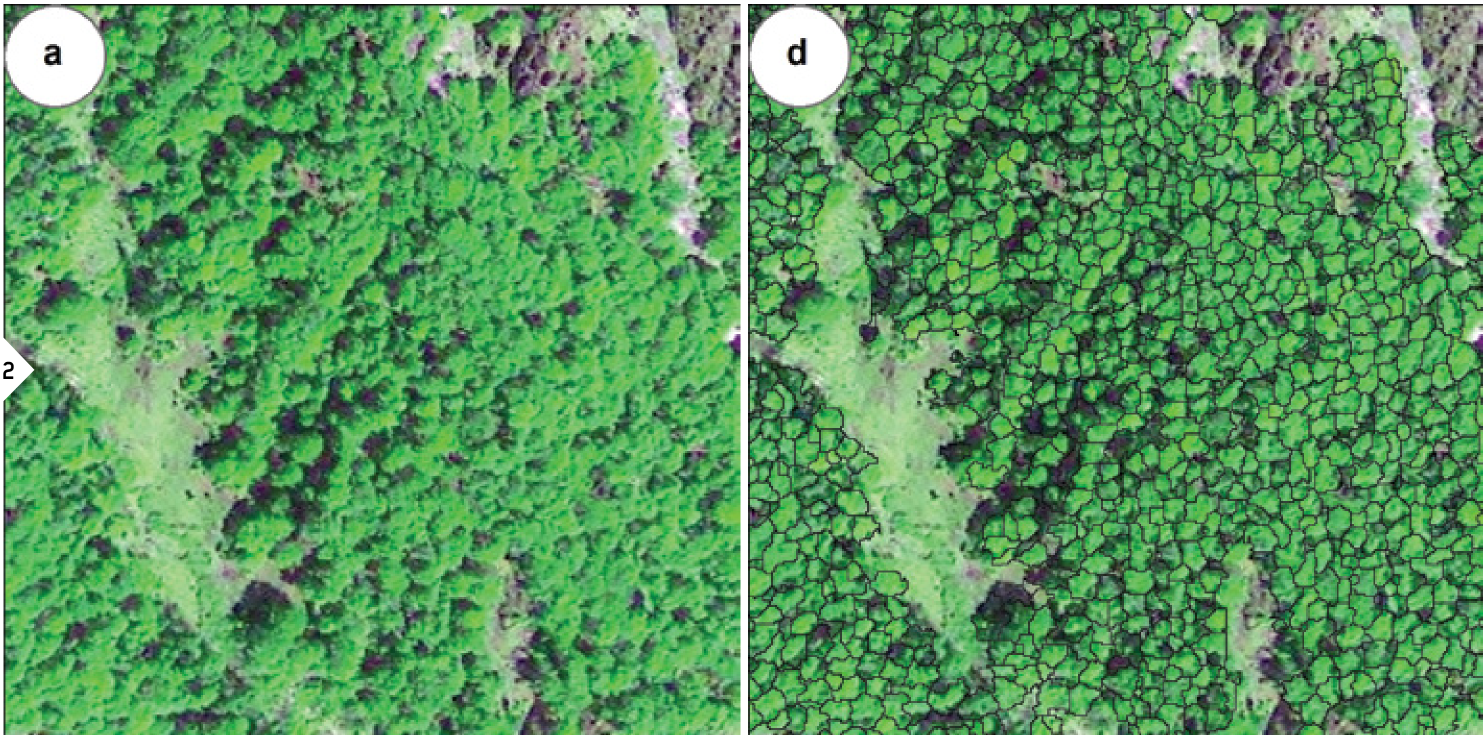
To validate the accuracy of eCognition's automatic tree crown detection, Uddin's team chose ten 2.5-acre (1-hectare) sections at random on each pan-sharpened QuickBird and Ikonos image and manually digitized each visible crown in ArcGIS. They then compared their delineations with the software's and found the 2011 tree-crown classification was 99 percent accurate while the accuracy for 2006 was 97 percent.

"For the purposes of this project, we not only wanted to detect trees, we wanted to determine the size of individual trees to visibly show the difference in forest cover in five years, and to quantify that visible evidence with concrete numbers of trees lost," says Uddin. "That would have been impossible to do by manually counting trees."

SEEING TREES THROUGH THE FOREST

With the land-cover maps completed, a small team from ICIMOD traveled to the Lorpa watershed to validate the accuracy of





▲ **FIGURE 2.** Counting tree crowns validated the software.

the 2011 map results with what was actually on the ground. Field teams manually assessed the vegetation at 60 randomly chosen sites and compared those findings to the land classification map. The overall accuracy was 93 percent, an impressive result – but not that surprising, says Uddin.

"We knew the capabilities of the software and were confident that it could efficiently and accurately classify and map challenging terrain, so we weren't that surprised by how well it performed," he says. "Local authorities, however, were shocked."

Indeed, in presenting the vegetation change detection maps to both officials with the MoAC and the local district forest office there were audible "gasps" at the clearly visible deforestation in the watershed area. Many officials were under the false impression that forest degradation had been improved in recent years because of successful community forestry programs. The imagery of Lorpa definitively proved otherwise. As sobering as the realization was, Uddin says the authorities were impressed with the detail of the maps, which they plan to utilize to help devise forestry-specific management programs for the watershed area.

The classification datasets were also used to help HIMALI project managers see how the vegetation changed over five years, enabling them to better understand the region's roots of historic deforestation and watershed erosion. With that knowledge, they could prioritize investment areas and develop community-centric strategies to help the villages organically grow a healthier agribusiness – both for the benefit of their own livelihoods and the wellness of the environment.

"With the remoteness of the high mountain areas, it's challenging for officials to obtain detailed information on ecosystems and the forest extent, and to measure that on a regular basis," says Uddin. "This geospatial and image analysis approach enables us to cost effectively assess the ground view and map it repeatedly. That approach can help increase the awareness of the problems, support the development of appropriate management plans, and provide a low-cost means to monitor the success of those plans."

Indeed, for the Nepalese, believing what they're seeing on the land-cover maps may not be enough to break their classic catch-22, but it may help them see the forest through the trees.

> "Using a combination of satellite imagery and advanced land-classification technology, they not only produced two land-cover maps showing Jumla's vegetation changes over time, they provided the visual truth to debunk some long-held, local beliefs that Jumla's forests were not being lost to deforestation."

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