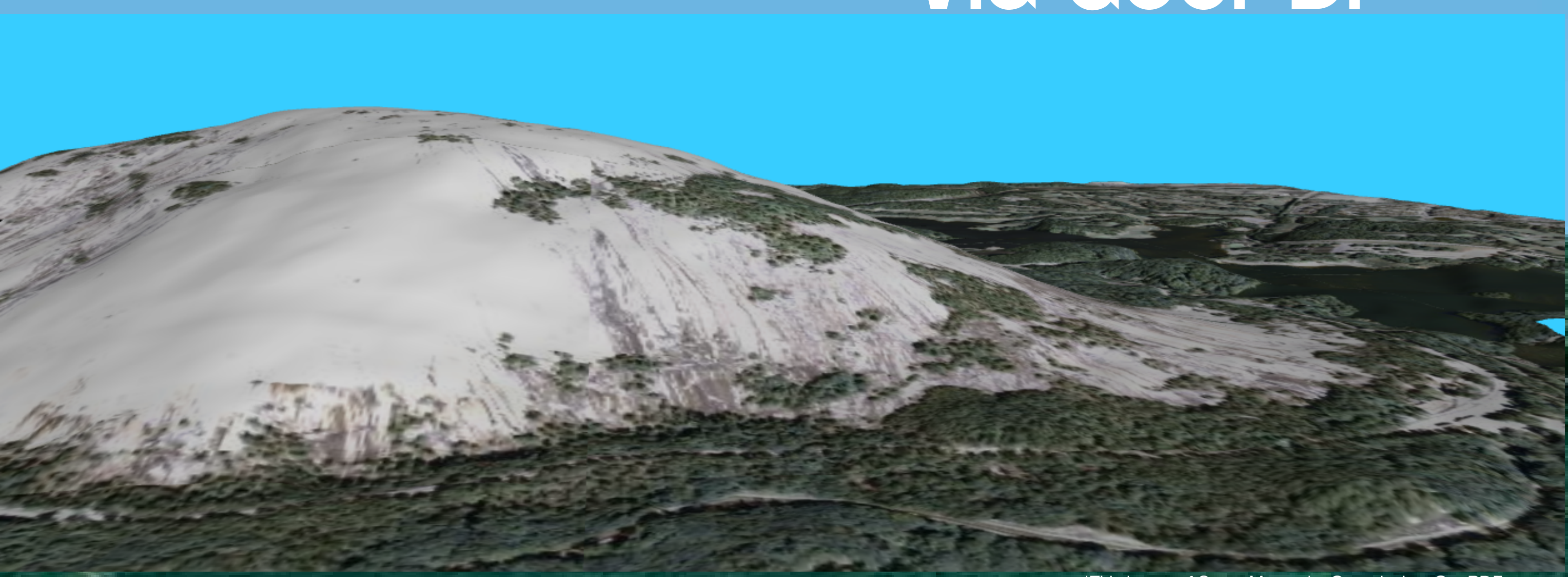
Imaging Notes

EARTH REMOTE SENSING
FOR SECURITY
ENERGY AND
THE ENVIRONMENT

Winter 2012
Vol. 27 >> No.1

Historic Preservation Via GeoPDF



*This image of Stone Mountain, Georgia, is a GeoPDF in the Digital Edition of *Imaging Notes*, so you can leverage the power of the geospatial information associated with the 3D PDF by using the free TerraGo Toolbar. See details on pages 8 and 26.

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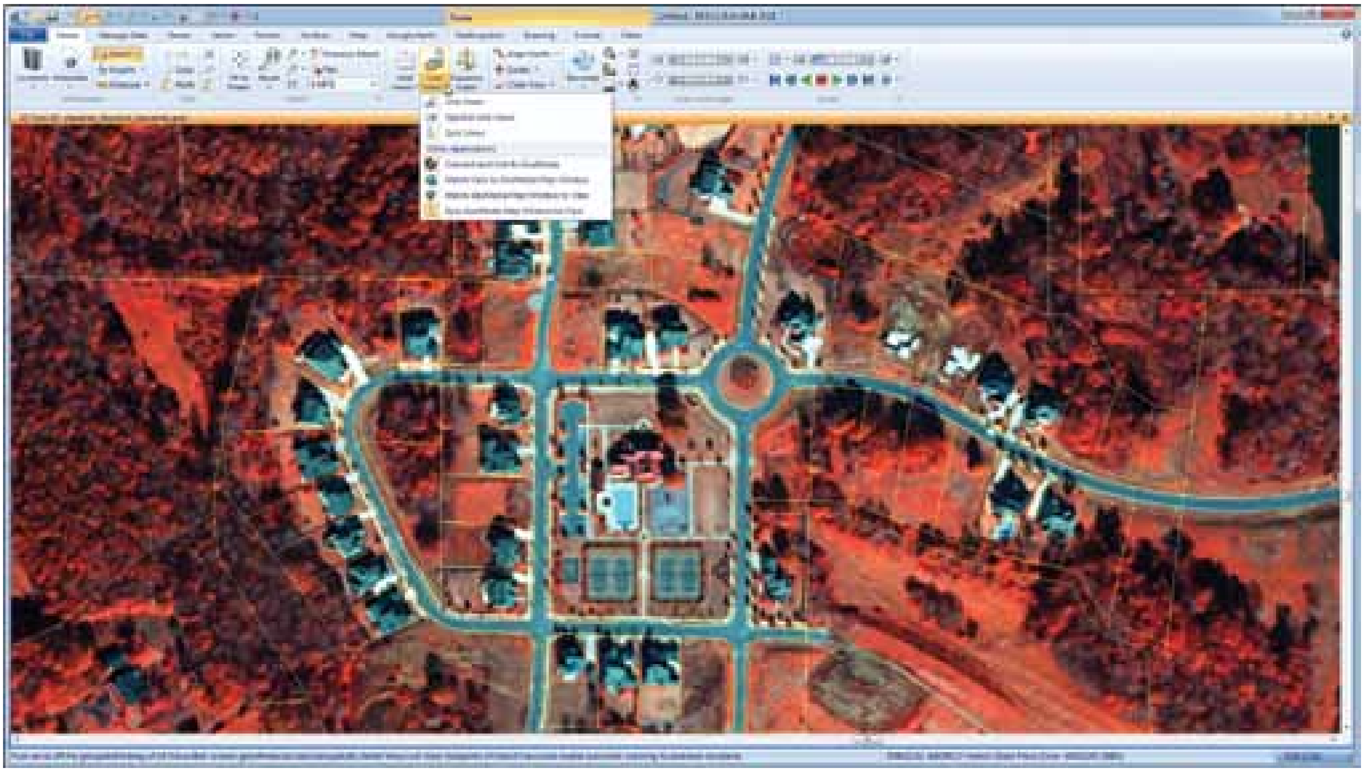


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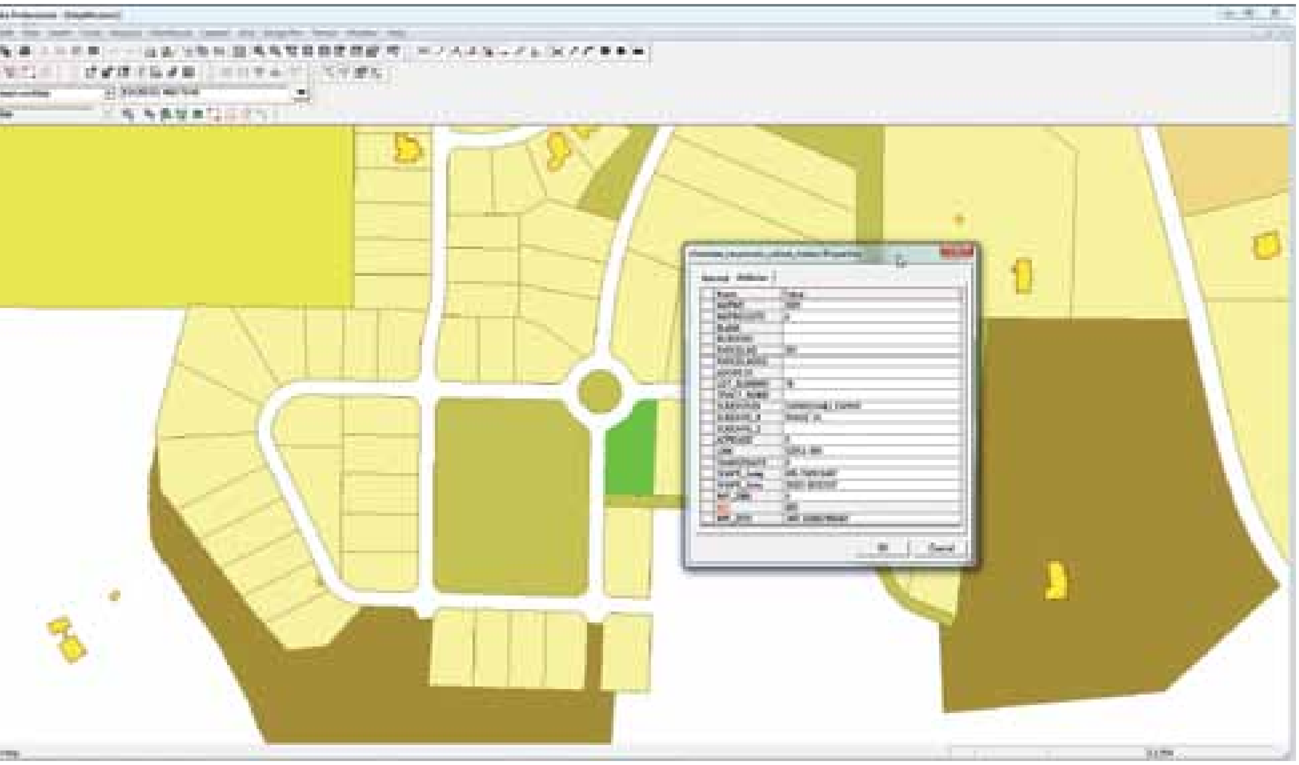

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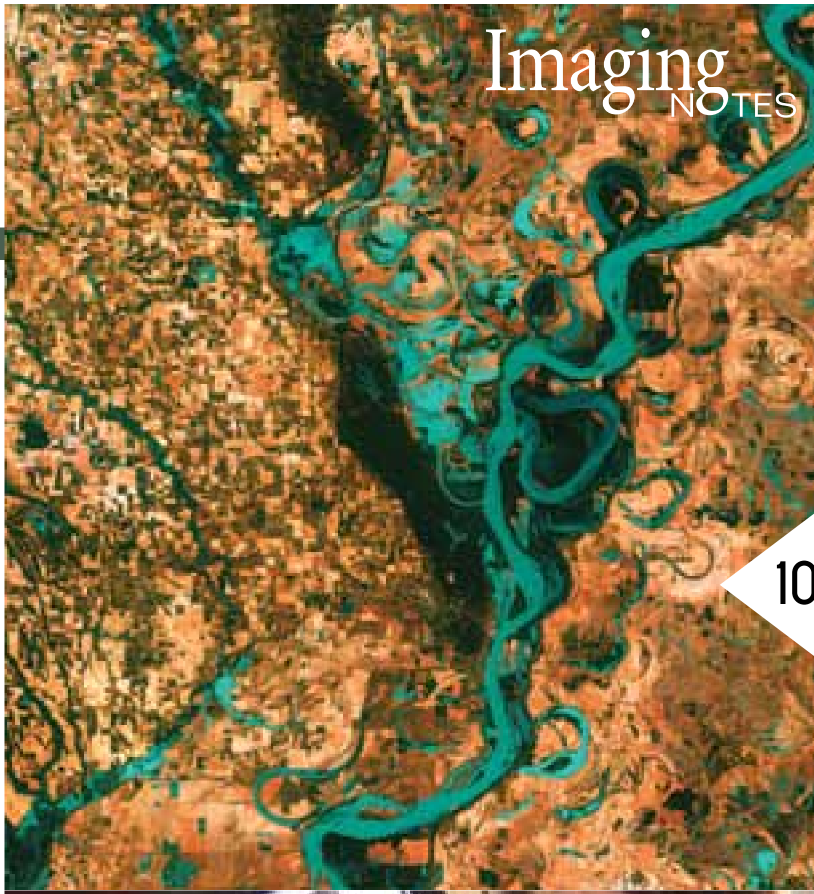

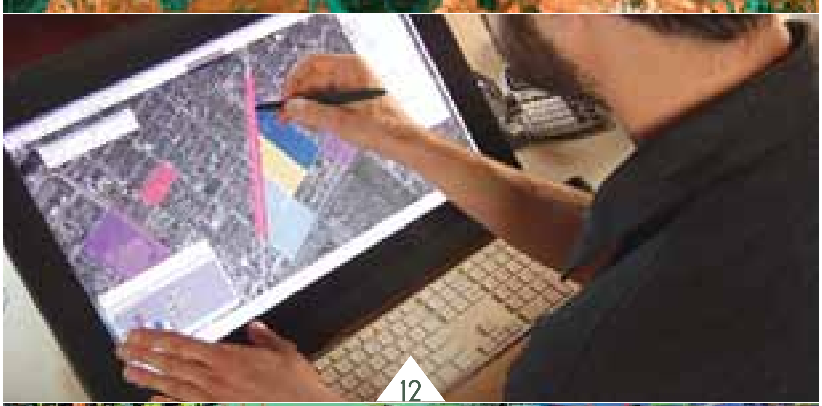

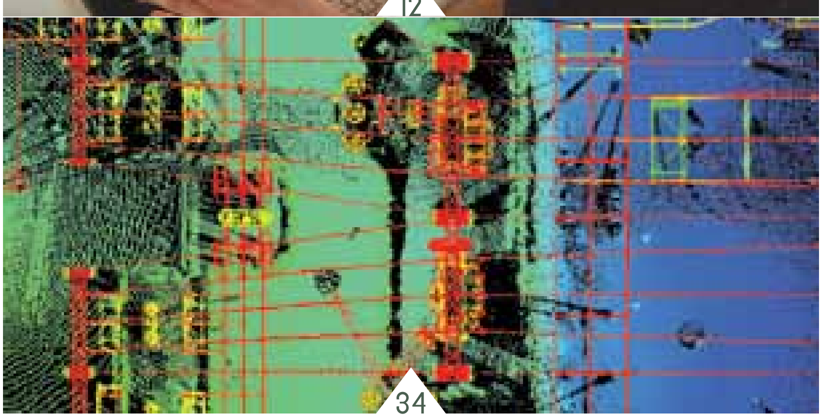

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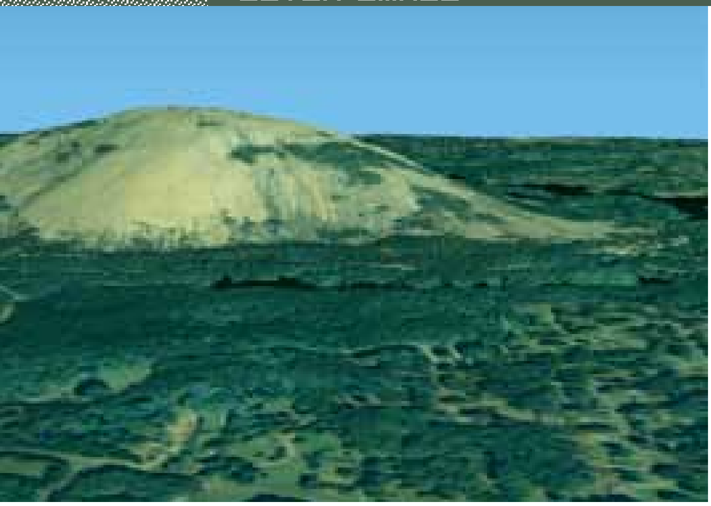
Stone Mountain, Georgia

COVER IMAGE



Imaging Notes *is thrilled to* publish and share for the first time in the media a GeoPDF image that is live within our Digital Edition!

Readers can see all layers of geospatial information associated with the 3D PDF by downloading the free TerraGo Toolbar at www.terragotech.com/products/terrago-toolbar.

Using the options under the TerraGo Toolbar drop down, you can view and interact with the geospatial information, including display of coordinates and elevation, measurements of length and line of sight. The TerraGo Toolbar makes it easy for everyone, including non-GIS-savvy users, to access and interact with complex 3D models.

For the complete story about TerraGo's GeoPDF, and how it is used in historic preservation, see page 26.

Stone Mountain is one of the world's largest exposed granite domes, located in Stone Mountain, Georgia, approximately fifteen miles east of downtown Atlanta. It is well known for its geology, as well as the large bas-relief sculpture depicting Jefferson Davis, Robert E. Lee, and Thomas "Stonewall" Jackson, Confederate leaders of the Civil War. Image courtesy of Northrop Grumman.

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Our Mission

Imaging Notes is the premier publication for commercial, government and academic remote sensing professionals around the world. It provides objective exclusive in-depth reporting that demonstrates how remote sensing technologies and spatial information illuminate the urgent interrelated issues of the environment, energy and security.

Imaging Notes has a partnership with Secure World Foundation (www.swfound.org).

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

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Climate Change, Health, and National Security

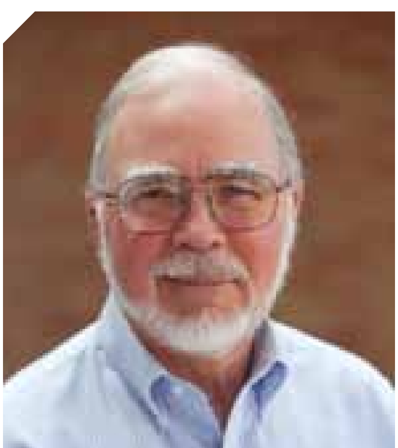
SECURE WORLD FOUNDATION FORUM

This July will mark the 40th anniversary of the launch of the first satellite in the Landsat system, a system that miraculously survived years of policy indecision, budget turmoil, technological challenges and interagency warfare to emerge today as the longest operating and most widely used electro-optical land remote sensing system in the world. Developed by NASA and now operated by the U.S. Geological Survey (USGS), the medium-resolution multispectral Landsat dataset constitutes the longest and most complete space-based global record of environmental change the world has. Landsat data, available for free download, are widely used throughout the world to tackle a broad variety of environmental issues.

The experience with Landsat data has paved the way for the operation of literally tens of other Earth observing satellites operating today, providing specialized data for a wide range of beneficial uses in support of human and environmental security. (A later column this year will review the long history of Landsat and future prospects for the Landsat Data Continuity Mission, scheduled to launch in December this year.)

As we move into 2012, I thought it worthwhile to review two quite different but important 2011 reports on the benefits of Earth observation systems that in my view have not received sufficient attention. The first is space policy analyst Lyn Wigbel's enlightening CSIS report, *Using Earth Observation Data to Improve Health in the United States: Accomplishments and Future Challenges* (http://bit.ly/zao5J7). This report reviews the utility of satellite Earth observing systems in combating disease and promoting health, and also warns that capitalizing on the gains made over the years is becoming more difficult.

The second report, a thoughtful product of the Center for a New American Security (CNAS), explores the role of Earth observing systems in supporting U.S. national security. In *Blinded: The Decline of U.S. Earth Monitoring Capabilities and Its Consequences for National Security* (www.cnas.org/blinded), national security experts Christine Parthemore and Will Rogers focus on the security risks we now face as those capabilities decline.



RAY A. WILLIAMSON, PHD, is editor of *Imaging Notes* and Senior Advisor to the Secure World Foundation, an organization devoted to the promotion of cooperative approaches to space security (www.swfound.org).

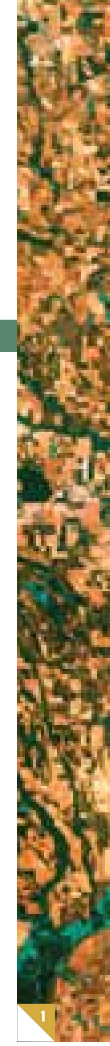
Although these two reports focus on quite different applications of Earth observing systems, they are nevertheless closely linked. Both illustrate the increasing utility of Earth observing satellites in support of human and environmental security, and both highlight the challenges faced by policymakers in continuing to operate these highly beneficial systems into the future.

The use of satellite systems to support public health is a subject that receives relatively little attention, but one that is likely to become increasingly important as climate change brings substantial environmental change to the United States and to the world, and as analytical models based on satellite data become more sophisticated. For example, changes in surface temperature, rainfall and other environmental factors have a significant role in the geographic spread of certain environmentally sensitive diseases such as malaria and West Nile virus.

In the United States, the incidence of Lyme disease, endemic in the Northeast, and Hanta Virus, more common in parts of the Southwest, are both affected by changing weather patterns. Although the mechanism of disease transmission is different in each, they share the characteristic that additional rainfall helps in promoting growth of animal populations that carry the diseases to humans.

Doctors in these regions often have trouble interpreting the symptoms these serious diseases exhibit in patients because they closely mimic other, less virulent ones. Observations from orbit of sharply increased vegetation growth in affected localities can assist public health officials in providing advance warning to local hospitals and doctors. This information can alert local doctors ahead of time to look for telltale signs of these diseases, thus saving lives.

Citing the Department of Defense's (DoD's) 2010 Quadrennial Review, the CNAS report reminds us that the department takes global environmental trends extremely seriously: they 'will shape the operating environment, roles, and missions' and 'may act as an accelerant of instability or conflict.' This is a theme that was first studied in detail in the 1990s in a series of detailed studies by Thomas Homer-Dixon of the University of Toronto



1

▲ **FIGURE 1.** *The graceful swirls of the meandering Mississippi River are surrounded by small, boxy shapes of towns, fields and pastures. Countless oxbow lakes and cutoffs accompany the river south of Memphis, Tennessee, on the border between Arkansas and Mississippi. The "Mighty Mississippi" is the largest river system in North America. Landsat 7 data acquired May 28, 2003, courtesy of USGS.*

and his colleagues, who examined the linkages among population growth, renewable resource scarcities, migration and violent conflict. Those studies made a persuasive case that although environmental degradation may not trigger violent conflict, it can exacerbate conflict and hasten outmigration from conflict regions.

Analysis based on satellite data provides an effective way to detect deleterious environmental changes that could lead to or aggravate conflict in a region. Since at least the Gulf War, military analysts have used both medium- and high-resolution data from a range of Earth observing satellites to understand real-time battlefield environmental conditions and long-term trends in order to fight more efficiently and to protect the troops from harm.

The CSIS report highlights a familiar problem in the structure of U.S. Earth observation technology development and use – the existence of a so-called 'valley of death' between the development and testing of an EO capability by NASA and its long term operation by NOAA or other agency focused on the operational utility of that capability. For decades, policymakers have insisted that NASA's proper role in the process is to develop space-based instrumentation in support of advancing science. According to this institutional model, if some of the sensors developed by NASA later prove successful in tackling societal needs such as public health or climate change, then they should be developed and operated by operational agencies like NOAA or USGS. This model has been much more successful in promoting leading edge Earth science than in bringing benefits to the public.

In reality, the money needed by the operational agencies for developing and operating new satellite sensors is seldom available to them, despite the clear utility of the collected data for their mission. As a result, the United States often cannot take advantage of the benefits such sensors would provide. For example, both reports cite the enormous utility of NASA's MODIS sensors for monitoring broad-scale environmental conditions in the United States and around the world. Data from these sensors are being widely used operationally by thousands of researchers to provide early warning of harmful environmental changes.

Yet, once these workhorse research sensors begin to fail, there are no planned replacements, despite years of effort to provide the funding for follow-on operational instruments. The VIIRS sensor on the recently launched NPOESS Preparatory Project (NPP) satellite will provide some of the needed data, but tradeoffs made in its design mean that some operational users will lose some of the MODIS capability they have depended on and will have to develop new algorithms to make effective use of the VIIRS data for their applications.

As we look ahead in 2012, we can hope that the continuing budget battles will not completely gut the U.S. Earth monitoring capability. Now more than ever, as these two reports illustrate, we need the ability to monitor Earth's environment from orbit to make use of the synoptic view that such observations provide.

GeoDesign: A Primer

REFRAMING AN OLD IDEA

SHANNON MCELVANEY is a Project Manager in the GeoDesign Services group at Esri, where he is currently writing a book of GeoDesign case studies. He was formerly the GIS and Site Control Manager for the $22B MASDAR City Development Program, developing the world's first carbon neutral, zero waste city.

EDITOR'S NOTE: Esri's Annual GeoDesign Summit was held Jan. 5-6, 2012 in Redlands.

▲ **FIGURE 1.** *ArcGIS 10 with its new template-based architecture makes sketching a design with instant feedback a reality using a Wacom tablet.*

DESIGN THAT CONSIDERS GEOGRAPHY HAS BEEN GOING on since humans started designing. Ancient cultures built settlements in close proximity to water and with good mountain views; they designed cities to maximize shading and natural cooling, and they positioned themselves in proximity to natural resources and trade routes. For thousands of years, design considering nature was, well, just natural.

Over time, 'progress' drove us away from these natural ways. Technological advances made it much easier for mankind to conquer – and even defy – nature. Today we extract resources at rates never seen before and we literally move mountains, often with little or no consideration for the environment. It was in this historical context that the architect Richard Neutra wrote *Survival through Design* (1954). An early environmentalist, Neutra's approach to architectural design applied elements of biological and behavioral science and stressed the "inherent and inseparable relationship between man and nature."

> *"Community planning is an art, but one in need of a large scientific advisory board, chaired by an expert in biology." -Richard Neutra*

In his book *Design with Nature* (1969), landscape architect Ian McHarg advocated a framework for design that helps humans achieve synergy with nature. In his view, design and planning that consider both environmental and social values in the context of both space and time help ensure a natural balance. McHarg's pioneering work using overlay analysis had a fundamental influence on the up-and-coming field of environmental planning and simultaneously solidified the core concepts of the young field of geographic information systems (GIS).

Both Neutra and McHarg advocated for design and planning where nature took center stage – a new way to design. While not an entirely new idea, designing with nature is now more feasible due to advances in software technology.

During the 2010 TED Conference, Jack Dangermond took a philosophical approach to the question of design by comparing a Japanese garden to a modern suburb. He proposed a 'designing with nature' renaissance, centered on GeoDesign as an alternative to traditional processes.

> ***"I believe that 'designing with nature,' or GeoDesign, is our next evolutionary step. GeoDesign is both an old idea and a new idea. It reopens our minds and hearts; it puts in our hands the means to achieve what the Japanese masters did so many years ago – designing with geographic knowledge, thus living harmoniously with nature." -Jack Dangermond, Esri founder and president***

These visionaries recognized the interconnectedness between humans and nature, that we have unintentionally created many of the problems we face today, and that we can ameliorate many of those problems through better design.

But we can't do it by using the same thinking that got us here in the first place.

GeoDesign is a new way of framing an old idea, made possible by new advances in science and information technology. The variety and complexity of information and technology have grown, changing the dynamics of decision making. Issues that arise are complex, emotional, and often political, but it is our responsibility to come together in open dialog if we are to design a better world for future generations. This dialog requires a new way of thinking, and a new way of working together.

Thinking GeoDesign

Born from landscape architecture, geographic information systems (GIS) technology has a complex pedigree. GIS and design have long been intertwined, hard to separate, and competitive. GIS was seen as the place for mapping, planning, and analyses at the macro and meso scale, while computer-aided design (CAD) was seen as a design tool for engineering and architecture at the meso and micro scale. Those boundaries, ill defined and arbitrary to begin with, are beginning to blur further with the introduction of GeoDesign.

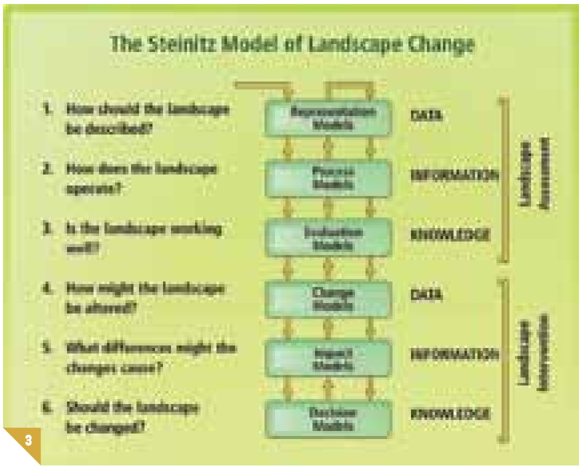
So exactly what is GeoDesign? It's a combination of geography and design.

Geography is about place and processes, the human and the natural, across both space and time. It seeks to organize, understand and describe the world.

Design is about intent or purpose. A creative act requiring imagination, design can produce something entirely new, or improve upon something that already exists. It often requires the creation of a sketch or model, followed by an iterative process of rapid redesign and evaluation of alternatives in order to attain the desired result.

GeoDesign combines the best of both these worlds, providing a new way of thinking that integrates science and values into the design process. By giving designers robust tools that support rapid evaluation of design alternatives and the probable impacts of those designs, GeoDesign provides the framework for exploring issues from an interdisciplinary point of view and for resolving conflicts between alternative value sets. In this sense, it can be seen as an integral framework for intelligent, holistic design that moves from designing around geography to actively designing with geography.

▲ **FIGURE 2.** *A four-lane boulevard with traffic calming features and bioswale for a median.*



▲ **FIGURE 3.** *Carl Steinitz's GeoDesign Framework uses a series of social questions to guide stakeholders through the process of landscape change.*

GeoDesign...

- is design in geographic space
- facilitates science-based design
- facilitates values-based design
- provides a framework for exploring issues and resolving conflict
- improves the quality and efficiency of design
- is multi-dimensional
- seeks to maximize benefits to society while minimizing both short- and long-term impacts on the natural environment.

GeoDesign in Action

Imagine picking up a stylus and sketching the initial design for a 4-lane boulevard through a new area of town, like this.

As you sketch in a GeoDesign environment, a chart informs you on-the-fly of the social and environmental impacts of the proposed design, such as:

- Construction cost
- Runoff
- Non-point source pollution
- Predicted vehicle-related deaths and injuries based on a 40 mph speed limit
- Estimates of air pollutants and their impact on health and climate.

The number of injuries and the amount of air pollutants are too high and need to come down. A glance at the chart shows that shielding pedestrians from vehicles by sketching trees between the road and sidewalk, and calming traffic by sketching in curb extensions, lowers the predicted impacts significantly, but not enough. An additional iteration is needed to meet the team's goals.

A decision is made to split opposing lanes with a median to further decrease vehicle-related death and injury. Someone then recommends changing the median type from concrete to a bioswale dotted with trees. These changes are sketched, and the chart reveals that the new design reduces runoff, non-point source pollution, and air pollutants while also reducing injuries. The team is satisfied with the latest design. See ***Figure 2***.

That is GeoDesign. It allows the designer to do their creative design work with the same ease as with pencil on paper, while receiving near

▲ **FIGURE 4.** *ArcGIS 10 has a report template that quickly summarizes and records the impact of your sketch against performance metrics supporting iterative design, comparison of those designs, and decision making.*

▶ **FIGURE 5.** *This light-rail planning sketch ties into the underlying road network giving a walkability map of the light-rail stops. This gives a visualization of the ¼, ½, and 1 mile walkability radius along the road network, i.e. what areas are well served by the light-rail stations. This can then be used to find areas suitable for re-development.*

real-time feedback on the impact of that design, thanks to GIS analysis being performed in the background. And that is the vision of GeoDesign: to provide a fundamental alternative to the way design is currently done, leading towards better solutions, better designs, and a better future.

The GeoDesign Framework

Carl Steinitz, professor of landscape architecture at Harvard University, first described how the GeoDesign Framework worked by posing it as a series of six questions relevant to landscape change. The first three questions describe the world as it is and assess its condition (the assessment process). The last three questions describe the world as it could be, evaluating proposed design alternatives and their impacts (the intervention process). See ***Figure 3***.

Assessment

The first question consists of abstracting geography into a series of inventory data layers. It is ***"How should the geo-scape (the planet's life zone) be described?"***

The second question, ***"How does the geo-scape operate?"*** requires combining geospatial data and the use of spatial analysis and modeling techniques to describe geographic processes and/or predict how spatial phenomena and processes might change over time.

The third question, ***"Is the geo-scape working well?"*** involves the creation of composite maps that combine a number of dissimilar things in a way that shows areas that are more favorable than others for certain activities. From Steinitz's point of view, the assessment process consists of examining existing conditions and determining whether the current conditions are operating well or not. Typically the assessment phase involves the participation of a diverse set of subject matter experts and stakeholders who are involved in defining issues, metrics, and the proper method of analysis.

Intervention

Once the assessment is complete, the geo-scape intervention process begins. The fourth question, ***"How might the geo-scape be altered?"*** involves the sketching of design alternatives directly onto a geospatially referenced surface or data layer.

The fifth question is answered by the quick evaluation of the impacts of those changes. It is ***"What differences might the changes cause?"***

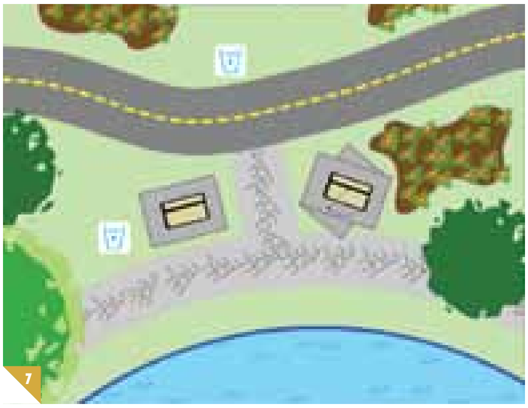
Finally, the sixth question, ***"Should the geo-scape be changed?"*** integrates considerations of policies and values into the decision process. The information produced by these impact models is used to help stakeholders and decision makers weigh the pros and cons of each decision factor so they can weigh alternative solutions and make the most informed decision possible.

> *GeoDesign can be seen as an integral framework for intelligent, holistic design that moves from designing around geography to actively designing with geography.*

GeoDesign in Practice

The GeoDesign Framework provides an excellent conceptual diagram for proposing changes to the geo-scape over any scale. However, as the project grows in scale and complexity, so do the analyses. That is where the GeoDesign Framework empowered by integrative workflows, intuitive design tools, GIS-driven geoprocessing, and feedback dashboards can really help to guide a design project from start to finish. ***Figures 4-5*** show planning for walkability distances to public transportation; ***Figures 6-7*** show sketches of public parks.

The specific ingredients of each project will be dependent on the issues, participants, available data, information, knowledge, culture, values, geographic context, and available technology. The goal is that the GeoDesign Framework will infuse design with a blend of values-based and science-based information made relevant by its geography and history to help designers and stakeholders make as wise a decision as possible, taking into account potential impacts.

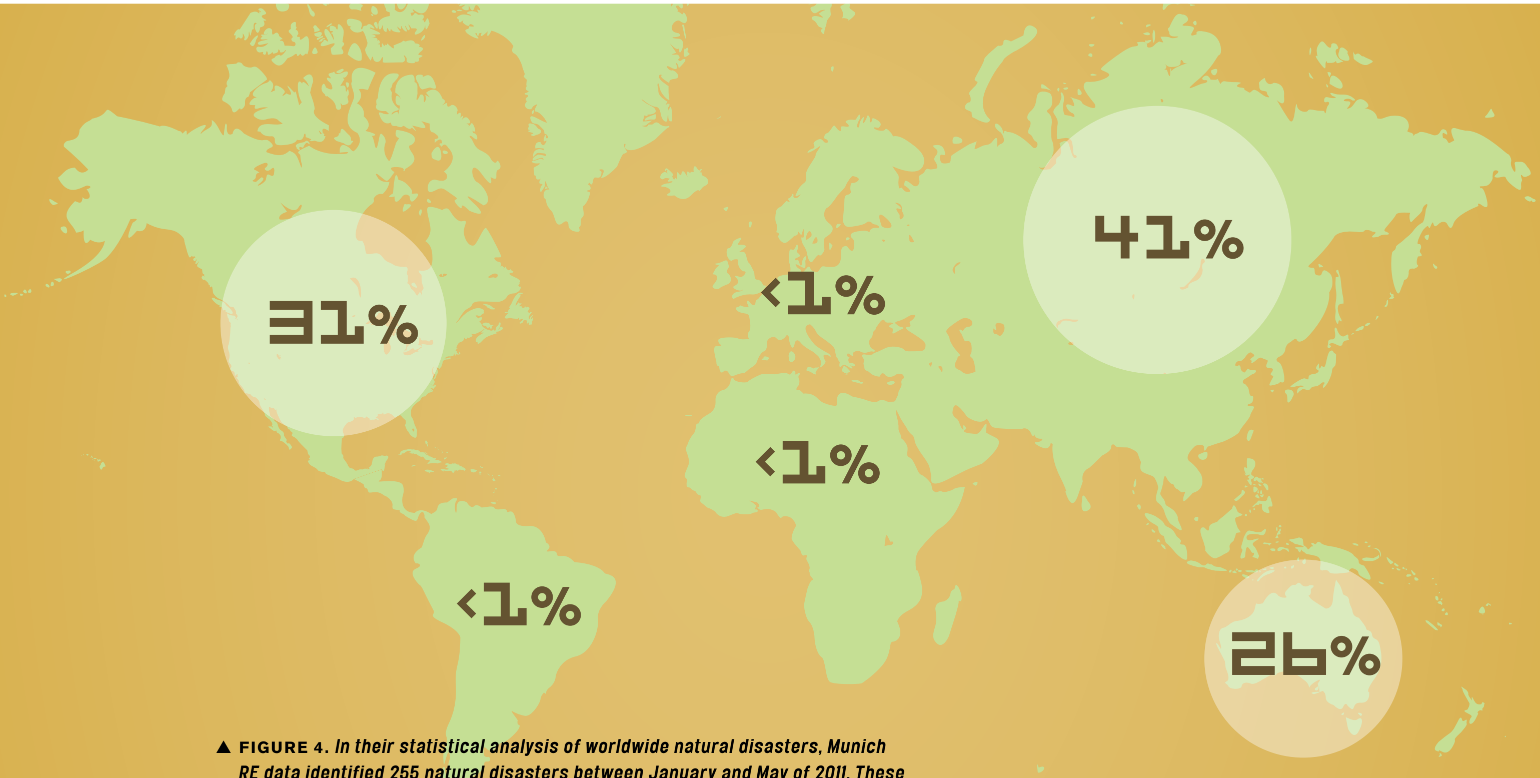


▲ **FIGURE 6.** *Using a template for park features that utilizes cartographic representations and a reference scale on the map, you can draw features in real-world distances. Trees and trail widths are consistent with your design specs, giving an instant visualization of the layout of the park.*

▲ **FIGURE 7.** *Placing features like park benches gives the ability to rotate the feature to the proper orientation by simply rotating the symbol or feature.*

Environmental Intelligence

A NATIONAL STRATEGY



▲ **FIGURE 4.** *In their statistical analysis of worldwide natural disasters, Munich RE data identified 255 natural disasters between January and May of 2011. These produced 31% of insured losses in North America alone.*

▼ *Participants of the Environmental Intelligence Roundtable: Three Perspectives on U.S. Needs. From left: Richard L. Engel (Major General USAF, Ret.), National Intelligence Council; Thomas R. Karl, L.H.D., NCDC, NOAA; Charles F. Wald (General USAF, Ret.), Deloitte Services LP.*

Continent	Insured losses (US$ m) in 2011 up to May
Africa	minor
America	15,300
Asia	20,000
Australia/Oceania	12,900
Europe	100

Introduction

This year, the United States experienced record-breaking extreme weather events and natural disasters. From devastating tornadoes, drought and flood, to hurricanes and record temperatures, every corner of the United States has been impacted. The National Oceanic and Atmospheric Administration (NOAA) estimates that in 2011, the U.S. has suffered more than ten billion-dollar disasters, with economic losses totaling almost $50 billion (see www.ncdc.noaa.gov/oa/reports/billionz.html).

Beyond U.S. borders, the situation is not much different, with ongoing recovery efforts from the earthquake and tsunami in Japan, storms in Australia, floods in Thailand, and extensive famine in the Horn of Africa. See ***Figure 1***. These events serve as a sobering reminder of the growing need for individuals, businesses and governments around the world to monitor the Earth's resources and understand the extent and impact of environmental changes.

With this context in mind, and amid a highly uncertain U.S. policy and budgetary environment, Earth observations leaders met in Washington, D.C. this past summer for the Alliance for Earth Observations signature event, *The Forum on Earth Observations V: Creating a National Strategy for Environmental Intelligence*. The Forum brought together a variety of government, industry and academic leaders to assess U.S. environmental information capabilities and examine the need for a national strategy for environmental intelligence – the most accurate and timely information about our planet, key to improved decision-making.

The final report of the Forum, released in September, captures the findings and recommendations of those who participated in the event as well as the contributions of various thought leaders who shared their views on how to improve the nation's environmental intelligence capability. Highlights of the report, discussed below, revealed shared concerns about how to meet global demand on environmental information, and how to strengthen the environmental information supply chain, as well as about the need to craft a comprehensive national strategy that ensures the availability of this critical information – now and in the future.

LAURA DELGADO LÓPEZ
Earth Observations Associate
Institute for Global Environmental Strategies (IGES)
Washington, D.C.
www.strategies.org

EDITOR'S NOTE: NASA, USGS, NOAA, Ball Aerospace & Technologies Corporation, CSC and Lockheed Martin Corporation sponsored the Forum. For more information and to download the final report, please visit www.forumoneo5.com. To learn more about the Alliance for Earth Observations, visit alliance.strategies.org.

Environmental Intelligence and Climate Change

Climate change is a 'threat multiplier' to the mounting pressures of a world population expected to reach 9 billion by 2050, according to Dr. Gerald Nelson, Senior Research Fellow at the International Food Policy Research Institute (IFPRI). IFPRI recently considered the impact of income and population growth in scenarios of food security through 2050. See ***Figure 2***. When climate change was added as a variable, the price increase of maize, a staple crop, was estimated to double from about 50% increase by 2050 to 100% in the same period (see ***Figure 3***). According to Dr. Nelson, environmental information is critical to understanding the state and changing nature of the planet in order to develop policies that 'increase the likelihood of sustainable food security even in a world with climate change.'

Climate change is playing a similarly central role in the short- and long-term planning of numerous sectors, including national security, as potential conflict and instability may arise with water and energy scarcity. These findings served to highlight the need for long-term, sustained observations from a variety of platforms for developing global forecasting models. The ability to build resilient communities that can withstand and easily recover from changes in climate depends on environmental information.

Key observations:

- **Environmental information is indispensable for individuals, governments and businesses to adapt to the growing costs imposed by natural disasters.**
- **Climate change is considered a critical national security issue. Meeting the challenges it poses requires a long-term planning perspective.**
- **Earth observations are fundamental to the activities of the U.S. agencies and other institutions engaged internationally.**
- **Unbalanced quality and availability of data hamper the delivery of global assessments of the changes and of growing demand on the world's resources.**
- **Climate change and the need for improved environmental information present an economic opportunity.**
- **Research must expand to be more multidisciplinary to incorporate the human component of a changing climate.**
- **Education and public outreach are key to addressing climate change and to fostering better uses of limited resources.**

Meeting Growing User Demand

Investments in U.S. Earth observation capabilities go well beyond national borders. In the flat world of the 21st century, the effects of disasters that occur in one corner of the world can be felt across continents. Talking about their impact on businesses, Carl Hedde, Senior Vice President of Munich Reinsurance America, described these events as 'contingent business interruptions' or 'business income loss.' As businesses around the world understand the impact of weather and climate on their bottom lines, environmental intelligence becomes an integral part of business intelligence and the basis for decisions that avoid losses down the road. ***Figure 4*** on page 16 shows geographic distribution of natural disasters.

Agencies engaged abroad and in the plant-based sector are part of a growing list of communities that now depend on environmental intelligence. To meet current demand and ensure continued U.S. leadership in Earth observations research and technologies, measurements must be sustained in the long-term, and better data sharing practices must be implemented.

Key observations:

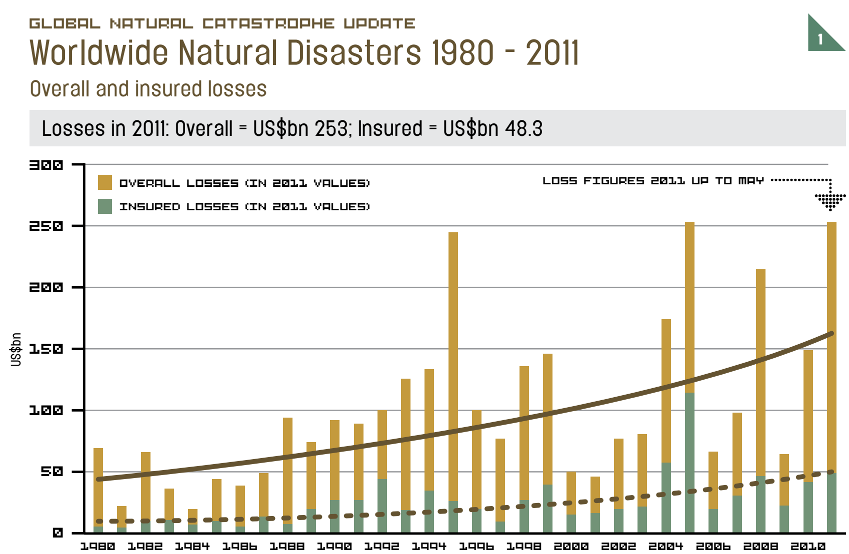
- A national strategy is needed that ensures long-term measurements and the widespread availability of Earth observations data.
- Meeting user needs can be improved. Better communicating the information that is collected is a necessary step in this direction.
- Landsat is one of the most important U.S. contributions to the world.
- The U.S. open data access is revolutionary and key to facilitating the use of important environmental information around the world. Data sharing standards are essential to enable different organizations and communities to share and use data.

A Changing Landscape

It is not business as usual in the Earth observations world. Budgetary constraints, advances in technology and a rapidly growing private sector are creating pressures and opportunities in the old environmental information data model. Government systems are now bolstered by academic, international and commercial platforms, such as the *in-situ* systems of companies like Earth Networks and Liquid Robotics. Matching user demand and doing more with less may depend on these kinds of innovative partnerships, where public-private partners share costs and risks and reap the benefits of improved global measurements. To support these initiatives, government can develop standards and design policies that facilitate these relationships while connecting the dots between taxpayer investments and the social and economic benefits enabled by these technologies.

Key observations:

- A paradigm shift for business intelligence is under way, with more industries realizing the important role of environmental information in the short and long terms.
- Opportunities exist for improved international cooperation.
- Fiscal constraints create opportunities to innovate.
- The data flow model is shifting. Assets include academic, international and commercial platforms, greatly augmenting government capabilities.
- Public-private partnerships are essential and must be improved.
- U.S. leadership in Earth observations should be leveraged to present greater economic opportunity for the nation.
- Given the difficult budget environment, the private sector is expected to play a greater role in the future.



▲ **FIGURE 1.** *During his keynote speech, Carl Hedde of Munich RE presented statistical analysis of natural disaster events and related losses. This graph shows overall and insured losses since 1980, indicating increases. Credit: Munich RE NatCatSERVICE.*

> *Our view here is – use science, use the observations we can get to better prepare America to take actions to prepare for something we can't avoid.*
>
> **– John L. 'Jack' Hayes, Ph.D., Assistant Administrator, Weather Services and Director, National Weather Service, NOAA**

Conclusion

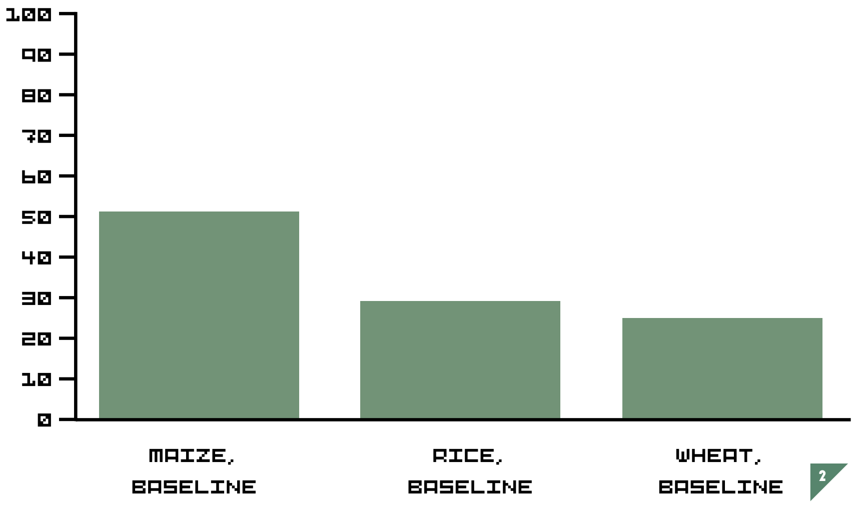
Environmental information does much more than tell us about the Earth's environment and resources – it also informs decisions. From small decisions at the individual level, such as whether to carry an umbrella, to big decisions at the community or business level, such as where to place a wind farm or how to define building standards, this information plays a fundamental role.

Environmental intelligence is an essential part of efforts to address the 21st century challenges – from transnational threats and food security to climate change. As was noted throughout the Forum, the United States' declining ability to monitor land, ocean, and atmospheric changes could have devastating consequences, particularly in the area of risk management. Experts agree that environmental intelligence must be a national priority, as it is essential to protecting our citizens, economy, and national security.

At a time of difficult budgetary decisions, the United States must develop a long-term strategy for environmental intelligence that ensures investment on the critical systems and programs upon which the nation and the world depend.

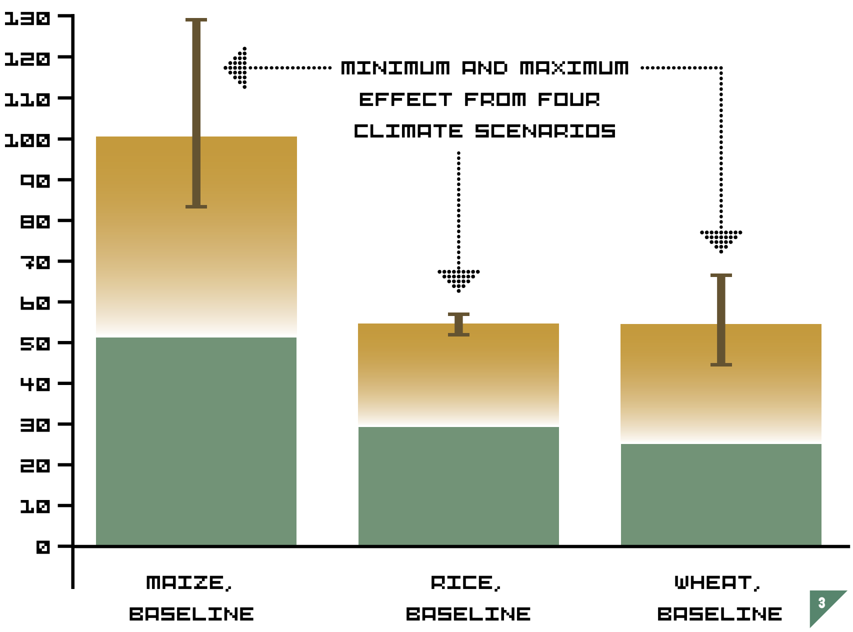
Income and population growth drive prices higher

Price increase (%), 2010 - 2050, Baseline economy and demography



Climate change increases prices even more

Price increase (%), 2010 - 2050, Baseline economy and demography



▶ **FIGURE 2.** *IFPRI researchers show that income and population growth increase food prices. This chart shows author estimates, based on analysis underlying Nelson et al, 2010. Monograph may be found at: www.ifpri.org/publication/food-security-farming-and-climate-change-2050.*

▶ **FIGURE 3.** *When climate change was added as a variable, prices increased significantly for three stable crops: maize, rice and wheat. Credit: Nelson et al, 2010.*

The Case for Commercial Imagery

THE BUDGET THREAT AND WHAT COULD BE LOST

HINDSIGHT (GUEST EDITORIAL)

Almost two years ago, I wrote an article here extolling the progressive virtues of the Department of Defense (DOD) and the National Geospatial-Intelligence Agency (NGA) in creating EnhancedView – a decade-long program to provide additional commercial satellite imaging capacity, upgraded ground architecture and value-added products and services to meet NGA and warfighter mapping and geospatial intelligence needs. Apparently, my enthusiasm got the best of me. The ink was barely dry on the contracts with GeoEye and DigitalGlobe before some in the Executive and Legislative Branches began to question the need for the program. The worsening fiscal situation has also brought EnhancedView – now NGA's largest program of record – increasing budget scrutiny.

The Administration has sent conflicting messages – President Obama has directed that over $400 billion over 10 years be eliminated from the Pentagon budget in the next decade. At the same time, the President endorsed the now so-called '2+2' future satellite imaging architecture in which two commercial-class satellites and two more sophisticated classified satellites would be built to meet future imaging requirements of the DOD, Intelligence Community, Department of Homeland Security and other government organizations.

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President
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Existing commercial imagery policy as well as the President's National Space Policy, and corresponding Department of Defense National Security Space Strategy, resoundingly endorse greater and sustained adoption of commercial technologies and partnerships to meet the needs of the U.S. government (USG). While no DOD program should be immune from budget tightening deliberations, EnhancedView remains exactly the creative public-private partnership model DOD needs in these challenging budgetary times.

Commercial capabilities have been serving the warfighting and intelligence communites and coalition partners for over a decade through both the Afghanistan and Iraq campaigns and in countless military contingencies, as well as humanitarian and environmental crises around the world. Commercial satellite images are commonplace in the media and in our daily lives through Google Maps or Bing and in numerous other location-based and commercial applications and services. Still, critics point to the large price tag associated with the 10-year program – over $7 billion – as justification enough to begin wielding the budget axe in the coming fiscal years.

Fortunately, the White House Office of Management and Budget (OMB) injected some discipline into the budget process for FY '13 and '14 by mandating a joint study by the Office of the Director of National Intelligence (ODNI) and the Under Secretary of Defense for Intelligence (USDI) to evaluate programmatic impacts on the industry as well as requirements satisfaction in an increasingly austere budget landscape. A report is due to OMB in mid-April 2012. As the joint team begins its review in earnest, they should be reminded of the commercial industry's virtues and strengths – key attributes that have been obscured during 'Inside the Beltway' studies in the past.

Virtues of the Commercial Imagery Programs

Commercial imagery is less expensive than that delivered by classified systems. Commercial ground and communications infrastructure costs are a fraction of the costs of national systems – cost elements that would have to be applied in any objective analysis of commercial and classified system costs. That said, the debate should not be about commercial versus national systems. Rather, it should be about what mix of commercial and classified systems meets which government mission needs and how the government should invest to ensure those capabilities are developed and maintained.

Commercial imagery is unclassified. Commercial imagery has been an important intelligence tool in every coalition or allied operation of the last decade, including Enduring Freedom and Iraqi Freedom and most recently during the North Atlantic Treaty Organization's (NATO) operations in Libya. Every year, testimonials abound at the U.S. Geospatial Intelligence Foundation (USGIF) GEOINT conference regarding the value and utility of unclassified imagery

Kandahar Airfield, Afghanistan, after an air strike. Image collected October 10, 2001, courtesy of GeoEye.

in the coalition context. U.S. and Allied warfighters need the data; they use it for mapping, operational planning, battle damage assessment and other geospatial intelligence needs.

Commercial imagery companies invest in systems that benefit the USG and taxpayer. Contrary to popular belief, the U.S. commercial satellite imagery industry launched their capabilities without a single penny from the U.S. Treasury. The industry invested close to $2 billion of corporate resources to launch the IKONOS, Quickbird and OrbView satellites in 1999 and 2000. The companies re-invested hundreds of millions of dollars in next generation capabilities in the NextView contracts and again most recently with EnhancedView. In addition to having these capabilities financed in part by commercial companies, the government then benefits from an aggressive discount pricing structure to ensure daily geospatial requirements continue to be cost-effectively met. The government's costs are further offset by the industry's growing international and commercial revenues.

Commercial imagery supports the space and intelligence industrial base. The commercial imagery industry is a robust and extensive ecosystem comprised of satellite manufacturers, subsystems developers, ground infrastructure hardware and software manufacturers, communications providers, launch system developers, and second- and third-tier parts suppliers. All of these partners contribute to the creation of the best commercial capabilities in the world. Most, if not all of them, support other important satellite programs for the USG. Their participation in the commercial industry provides diversity of experience as well as continued refinement of their technology and capabilities, which have secondary benefits for other government programs.

Commercial imagery incubates other commercial business and activities. The market for commercial imagery continues to evolve. While it is true that the industry's revenue mix tilts decidedly towards defense and intelligence business, GeoEye and DigitalGlobe continue to develop and serve international and commercial markets. Each company manages a global affiliate and partner supply chain that utilizes commercial imagery for regional or individual market segments – real estate, oil and gas, and transportation, as well as location-based services and a growing list of ubiquitous online mapping applications.

Commercial imagery meets the government's needs. Commercial imagery provides daily value to defense, intelligence, homeland security analysts, operators and policy-makers. The capabilities flying today and in development for tomorrow are leading-edge commercial technologies that address a large majority of national security geospatial intelligence demands. The government will likely see large savings in the defense budget with the military's exit from Iraq and eventual troop drawdowns in Afghanistan. Ironically, the need for comprehensive Intelligence, Reconnaissance and Surveillance capabilities in that region as well as other global hot spots will only increase.

As noted above, the budget debate shouldn't focus on commercial or classified. They are two different classes of systems that were developed to address different intelligence and information needs. The USG cannot afford to be without either capability. The relative speed with which some parts of the government have begun a reconsideration of the program is somewhat startling given the industry's obvious benefits to the DOD. More importantly, the companies are performing daily collection well and efficiently executing their EnhancedView contracts.

In Shakespeare's *King Richard II*, the Earl of Salisbury, in a fit of nostalgia, says, "O, call back yesterday, bid time return," (Act III, Scene ii). The Administration got it right with the 2+2 decision almost two years ago. While we can't go back to 2009, the White House and Congress should stick to the original '2+2' that launched EnhancedView, ensuring that the Nation has the most capable and diverse overhead architecture for tomorrow.

QA/QC Challenges with Lidar

TECHNOLOGIES EVOLVING

To ensure a quality product in any LiDAR project, good Quality Assurance and Quality Control (QA/QC) processes must be in place from the beginning. This is a common sense statement but the devil is in the details. A QC program should be part of any initial project design, for measurement and checking each step of the process. Then, to verify results, QA is conducted during the process and before delivery to ensure the project meets client requirements.

LiDAR is a rapidly evolving technology in all aspects. The hardware, software, and processes continue to develop, and client expectations are rising, too. Implementing a QA/QC program in every project will help to ensure continuous quality improvement, increased productivity, and decreased cost from project to project with best practices that are repeatable and measurable.

The huge volume of data that is generated by LiDAR can be overwhelming. So, having smart processes designed to build in quality, such as using referential Ground Control, aids in processing the raw data correctly in the first place.

W. BRANT HOWARD is the co-founder and CEO of CompassData, one of three businesses based on GIS, GNSS and wireless technology. He developed the innovative idea of owning and licensing Ground Control Points (GCP), and created the CompassData GCP Archive to provide standardized, accurate GCP at five precision levels. Howard makes numerous presentations for seminars and conferences around the world and has authored articles for technical journals on Geology, Survey, GIS and fleet management topics. Memberships include GITA, ASPRS, CSIA, APWA, and MAPPS.

It's a good idea to base your QA/QC plan on known standards and professional judgments, both internal and third party, and to include those in the process plan. The importance of good professional judgment cannot be overstated, as the standards themselves are evolving along with the technology.

In fact, QA/QC is actually needed twice: Fundamental Vertical Accuracy (FVA) testing for the initial data, which verifies the data are ready for the 'bare earth' processing,

FVA-POINTS	DATE	SV'S	PDOP	VERT PREC	HORZ PREC	NORTHING (GPS)	EASTING (GPS)	MSL (GPS)	MSL (LIDAR)	Δ Z	Δ Z^2
CMG301	11/30/10	15	1.1	0.007	0.005	4831025.254	635145.597	458.050	458.14	-0.09	0.0081
CMG302	11/29/10	14	1.5	0.007	0.004	4826978.616	649776.782	441.250	441.29	-0.04	0.0016
CMG303	11/30/10	12	1.6	0.011	0.007	4830974.380	660626.588	429.283	429.36	-0.08	0.0059
CMG304	11/30/10	10	1.7	0.019	0.013	4840243.533	667006.799	478.453	478.49	-0.04	0.0014
CMG305	11/30/10	11	1.7	0.012	0.007	4840534.610	681497.823	466.480	466.45	0.03	0.0009
CMG306	11/30/10	11	1.8	0.012	0.008	4822546.476	669046.473	464.296	464.39	-0.09	0.0088
CMG307	11/30/10	13	1.4	0.006	0.005	4824731.628	693097.301	435.660	435.68	-0.02	0.0004
CMG308	11/29/10	13	1.4	0.007	0.006	4816449.568	683665.045	440.477	440.45	0.03	0.0007
CMG309	11/29/10	14	1.8	0.009	0.006	4808021.187	667748.875	480.802	480.80	0.00	0.0000
CMG310	12/1/10	14	1.4	0.006	0.005	4808738.342	698380.223	405.996	405.99	0.01	0.0000
CMG311	11/29/10	14	1.3	0.009	0.006	4802132.546	690670.308	388.126	388.18	-0.05	0.0029
CMG312	11/29/10	9	2.4	0.016	0.010	4789539.248	706537.222	371.512	371.57	-0.06	0.0034
CMG313	12/1/10	11	1.7	0.011	0.008	4781892.023	713202.930	363.987	364.01	-0.02	0.0005
CMG314	12/1/10	12	1.4	0.006	0.003	4770667.911	722912.789	386.334	386.33	0.00	0.0000
CMG315	12/1/10	12	0.8	0.005	0.003	4828441.717	711797.436	431.340	431.47	-0.13	0.0169
CMG316	12/1/10	14	2.3	0.008	0.004	4822220.309	720034.866	415.201	415.05	0.15	0.0228
CMG317	11/29/10	9	2	0.016	0.010	4817215.640	713749.512	423.847	423.86	-0.01	0.0002
CMG318	12/1/10	14	1.3	0.007	0.005	4809254.844	717214.604	407.806	407.75	0.06	0.0031
CMG319	12/1/10	13	1.5	0.008	0.004	4802685.706	714171.685	394.261	394.41	-0.15	0.0222
CMG320	12/1/10	13	1.6	0.011	0.005	4799734.917	723885.584	395.337	395.29	0.05	0.0022

METADATA
UTM 14 NORTH, NAD83, NAVD88
ALL UNITS IN METERS WHERE APPLICABLE.
MSL = GEIOD09

Z MEAN	0.06	RMSE:	0.071
Z MIN:	-0.15	* 1.9600	0.140
Z MAX:	0.15		

▲ **FIGURE 1.** *This is a Fundamental Vertical Accuracy (FVA) test, which provides a check on LiDAR accuracy based on ASPRS precision levels standards. All the points in columns A through I are surveyed and were supplied either by Ground Control Points or new field data collection. The LiDAR vendor provides the data in column J; then the difference is calculated. This provides the statistical summary, based on the differences, to summarize the LiDAR quality.*

building recognition, or determined next steps (see ***Figure 1*** for example). This is followed by a Consolidated Vertical Accuracy (CVA) test, performed for verification of the bare earth model.

By finalizing with an independent data validation, project managers can assure that they are producing the very best for their clients.

In LiDAR, just as in photogrammetry, there are typical points of failure, and because we know where those generally fall, we can usually catch them through standardized QA/QC so they can be corrected.

Common Error-Producing Issues in LiDAR Projects

When the LiDAR collection is first planned, project managers design the flight lines in order to have small overlaps in the data. The overlap is crucial for well-balanced and controlled texture, ensuring that the data will come together smoothly. If there is a missing overlap, it is difficult to stabilize the flight lines, by sewing them to each other. For example, in a grid with six flight lines, line four is tested by lines five and three. If there is an opening or a gap between the lines, then there is a lack of stability in the final results.

Another typical issue that can result in errors in LiDAR data has to do with the technical components of the collection and the project realities, such as topography, and weather during collection. It is a complex system, pulling together the GNSS from the airplane, the IMU and the LiDAR sensor. The components have to work flawlessly together as the plane is flying quickly over the landscape.

The GNSS technology is solid, but cycle slips or similar failures still occur occasionally. The IMU component also works very well, but there are some technical problems that can occur here too: moving bias errors (for instance, 'sensor drift') and random errors. The GNSS unit helps to stabilize the IMU, but minute problems can happen.

Related to the IMU, before every LiDAR collection flight there is a calibration protocol, but it's not consistently done, or done completely all the time. This is a sensitive thing to point out, because this brings human error into the equation. Consider that the calibration protocol for a particular project takes around 15 minutes, before every single flight. Occasionally, the pilot doesn't want to wait the full 15 minutes. It's gone fine for every previous flight, every day for several days, so why not take off after eight minutes, or nine?

Different IMU models require different calibration procedures, and the atmospheric conditions at the time of collection can affect the calibration (when the plane compensates for strong wind, for instance). Calibration issues do not create errors – yet – but they could result in one. And finally, the laser unit is a complex piece of the technology itself, and problems can occur here too.

None of the above issues is unusual, and most can be fixed through data processing as long as there is a stable set of Ground Control Points (GCP) available to ensure the data collected is accurate. For instance, an evenly distributed set of GCPs, surveyed in the field, strengthens the entire texture of the collection. Now, the line four mentioned above might not contain a GCP – but because it's tied to lines three and five, the GCP helps to stabilize the entire collection. GCP surveys can be a source of error if not performed properly, and must be reviewed and measured as part of the QA/QC process.

Once the LiDAR data are collected, it is up to solid QA/QC to find and correct the issues mentioned above.

Millions of points are gathered in a LiDAR collection, so in processing, it is usually cut into tiles to create manageable amounts of data at a time.

LiDAR offers a number of different uses, so for purposes of this article, let's assume we're working with a LiDAR collection to ascertain flood plains. Within the tiles of data, the operators work through map layers to remove the vegetation and the man-made structures from the imagery. We use the software to remove those items, to calculate areas prone to flooding, looking for points on the ground among the vegetation in order to find actual ground elevation – 'bare earth.'

The operator's competency is very important at this stage, in order to direct the software algorithms correctly. Other uses of this technology that require a different density of points and slightly different processing include looking for power lines and other items at a height above the ground, urban infrastructure modeling, etc.

Once the processing has been done to remove the vegetation, man-made structures and artifacts from the imagery, the QA/QC process should be brought back into the picture. In doing that, we look at random points within the tiles: we ask what elevation do you have here, or here. We reference the model against Ground Control Points. Using a method of distributed GCPs through the series of tiles, across the full project, we can put together a verification of the elevations. We can verify that it meets reality and is not skewed by some dense vegetation or a crumbled structure that the software would not have found obvious and inaccurately modeled.

Standards in QA/QC

The basic tenet of standards such as FEMA's PM61, that Ground Control should be used to develop the surface, then once collection is done, an independent QA/QC should be conducted to prove the verification, is still a valid requirement. Current standards generally reference each other, and with the rapidly changing LiDAR technology, they are constantly in a state of revision. This changing environment requires professional judgment in the development of each program.

Regardless of how careful the initial collection is and how thoroughly the project is planned, it's still vitally important to require independent QA/QC performed by a neutral independent third party before turning a project over to a client.

"Just as we use ground control to improve the product, using independent checkpoints to validate, we should use independent software to check the data for quality," said Dr. Chuck O'Hara, President of Spatial Information Solutions. "LiDAR production happens through a series of teams: the flight itself, the surveying team providing ground control, then the processing team, and an independent check on all of that. It's rare that the same people are working on it across the board, which makes an independent QA/QC process even more crucial."

O'Hara's product automates the verification process using ground check points and produces a report that meets requirements of such organizations as FEMA.

Whether from a software supplier, an independent third party firm, or as part of your own internal QA/QC, it's best practice to check your results through the FVA and CVA processes and to use Ground Control to validate throughout. Constant process improvement means successful projects and happy clients.

In the final analysis, it's the client requirements that we should be most concerned about. If we produce consistently accurate results, using standardized processes so that we can do this faster and smarter each time, the clients will continue to order the projects, and the data we collect and share with the world will continue to be seen as valuable. QA/QC processes ensure this.

LIDAR STANDARDS

a. FEMA PM61 (FEMA Procedure Memorandum No. 61) – Standards for LiDAR and Other High Quality Digital Topography, published September 27, 2010.

b. ASPRS Data Standards – LAS v 1.3 www.asprs.org/society/committees/standards/lidar_exchange_format.html

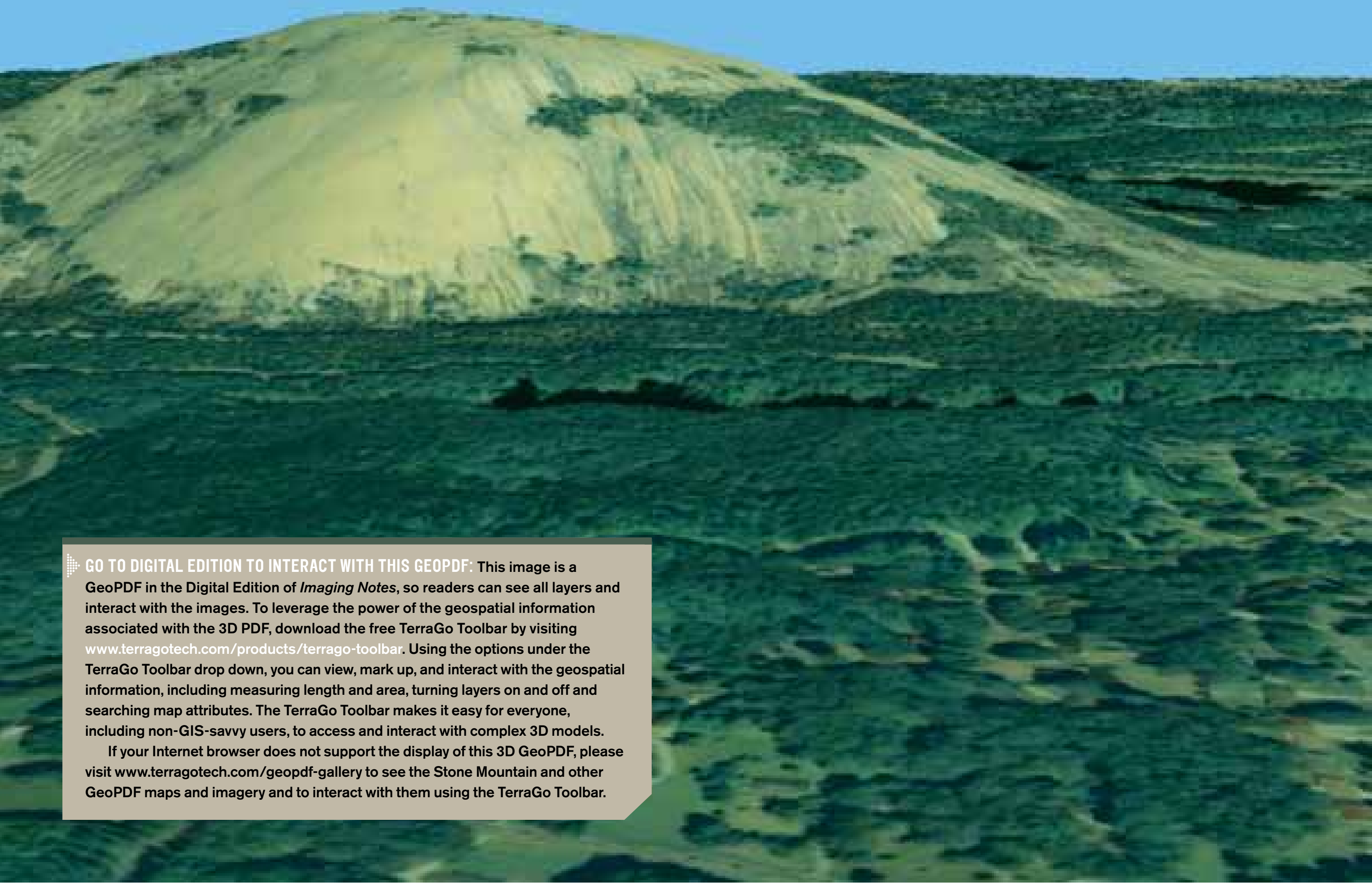
c. National Standards for Spatial Data Accuracy (NSSDA) – Standards for accuracy verification and testing that are applied for most LiDAR projects.

d. USGS V13 – United States Geological Survey LiDAR Guidelines and Base Specifications Version 13.


RUTHS SHOP

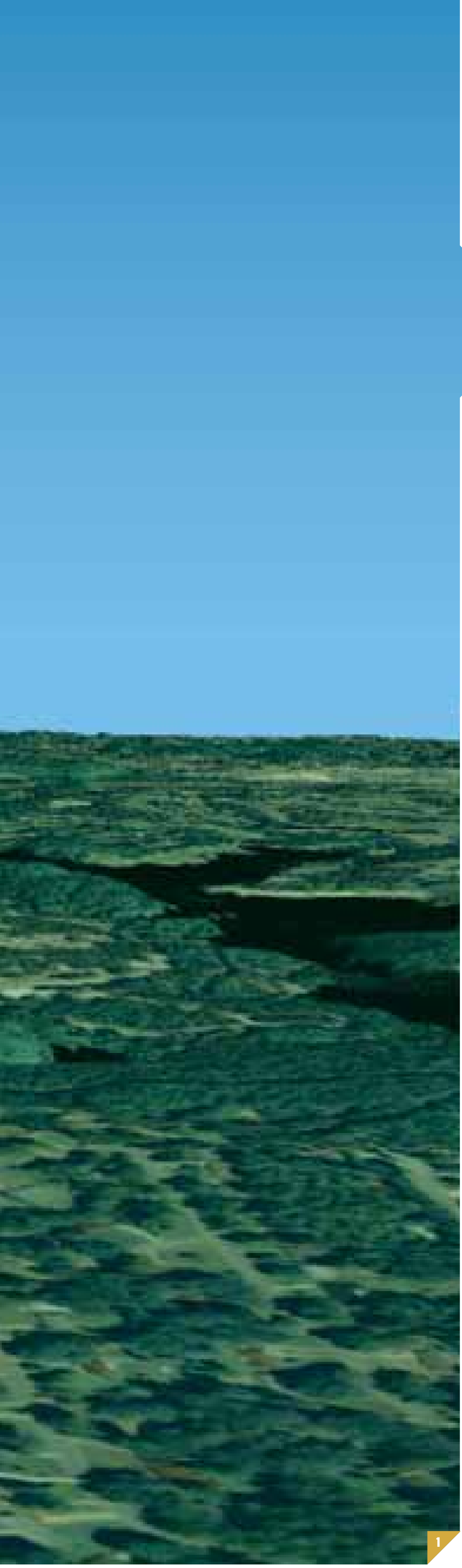
Historic Preservation

BRIDGING THE GAP BETWEEN GIS EXPERTS AND FIELD RESEARCHERS



GO TO DIGITAL EDITION TO INTERACT WITH THIS GEOPDF: This image is a GeoPDF in the Digital Edition of *Imaging Notes*, so readers can see all layers and interact with the images. To leverage the power of the geospatial information associated with the 3D PDF, download the free TerraGo Toolbar by visiting www.terragotech.com/products/terrago-toolbar. Using the options under the TerraGo Toolbar drop down, you can view, mark up, and interact with the geospatial information, including measuring length and area, turning layers on and off and searching map attributes. The TerraGo Toolbar makes it easy for everyone, including non-GIS-savvy users, to access and interact with complex 3D models.

If your Internet browser does not support the display of this 3D GeoPDF, please visit www.terragotech.com/geopdf-gallery to see the Stone Mountain and other GeoPDF maps and imagery and to interact with them using the TerraGo Toolbar.



Our nation is fortunate to encompass a treasure trove of sites and landscapes that shed light upon the history of America. However, while these sites and landscapes are a rich, celebrated part of America's evolution, they require proper preservation planning services to maintain the historical integrity and, in many cases, the aesthetic beauty. Many of these sites need cultural resources studies, such as analyses of cultural landscapes, archaeological and architectural surveys, evaluation and mitigation to ensure that they will provide lasting value for many generations to come.

Gray & Pape, Inc. provides these types of services to plan mitigation activities and related expenditures for archaeological and architectural resources for some of the nation's most storied sites. The firm's highly specialized analysts and researchers expertly identify archaeological and architectural resources for a wide range of projects. In addition, the firm caters to a diverse set of clients, including consultants and project managers, as well as public relations, land planning, engineering and construction professionals.

From Paper to Digital

A typical project for Gray & Pape includes the firm's in-house GIS experts, the client GIS resources and the archaeologists and historic architects who analyze sites and collect information in the field. The latter subject matter experts often have little or no direct experience with GIS. The firm's projects have in the past relied on a paper-based field data collection process.

Maps used in the field were printed from the GIS and delivered to the experts in the field. These paper maps were then annotated with notes and sketches based on observations in the field. After markup, the maps were returned to the GIS technician who then translated the hand-written notes and drawings into entries in the GIS, which were

GEORGE DEMMY is Chief Technology Officer at TerraGo Technologies. Demmy is one of the patent holders for the process that creates georeferenced PDF files. He holds a BA in Physics from Florida State University and an ME and Ph.D. in Agricultural Engineering from the University of Florida. He comes by his interest in historic preservation naturally; his father and namesake is the former director of historic preservation for Pensacola, Florida.

◀ **FIGURE 1.** *Stone Mountain is one of the world's largest exposed granite domes, located in Stone Mountain, Georgia, approximately fifteen miles east of downtown Atlanta. It is well-known for its geology, as well as the large bas-relief sculpture depicting Jefferson Davis, Robert E. Lee, and Thomas "Stonewall" Jackson, Confederate leaders of the Civil War. Image courtesy of Northrop Grumman.*

◀ **FIGURE 2.** *Snapshot of a GeoPDF created to support the project design process for a new highway that crosses an archaeologically sensitive area. Layers that can be turned on and off include multiple versions of the project alignment, known and potential archaeological resources, and sources of disturbance such as a rapidly migrating stream channel.*

SIDEBAR 1

Mobile GeoPDF Solutions: On-Demand GIS Anywhere, Anytime

To accommodate the rapidly growing numbers of tablet and smartphone users, TerraGo has launched TerraGo Mobile, which allows field personnel to easily access, update and share geospatial information peer-to-peer in the field and back to the enterprise.

This solution allows anyone who can open a PDF file to instantly improve situational awareness; capture current, geo-referenced multi-media updates in connected or offline environments; and share geospatial intelligence with anyone anywhere. TerraGo Mobile is applicable to defense and intelligence, crisis management, utilities and oil and gas organizations, as well as others with large field/mobile workforces who rely on enterprise geospatial information.

The software currently operates on Trimble Juno, the Juniper Archer and Mesa Rugged Notepad, and Topcon GMS-2 Pro handheld devices using the Microsoft CE 6.0 and 6.5 mobile platforms. TerraGo Mobile for Google Android and Apple iOS will be launched in 2012.

subsequently analyzed. Unsurprisingly, field subject matter experts often did not use GIS tools directly to analyze the data or view historical maps and images.

Gray & Pape's GIS team saw the need and the opportunity to create a bridge between these workflows to enable seamless and easy digital sharing of GIS data and field observations between the GIS experts and the archaeologists and architectural historians conducting research. Gray & Pape tapped TerraGo Technologies for its geospatial collaboration expertise and software to allow their clients the ability to extend the access and application of their geospatial assets by creating highly portable and interactive GeoPDF maps and images out of complex GIS data. With TerraGo GeoPDF maps and imagery, users can more effectively capture intelligence from the field and 'roundtrip' the data back to the enterprise GIS.

Working with GeoPDF maps and imagery is simple and highly intuitive, offering vast improvements over paper-based processes. Users open GeoPDF files with Adobe Reader, as they would any PDF. However, GeoPDF maps provide views to map layers and feature attributes, which heretofore were typically limited only to GIS. Moreover, with TerraGo Toolbar, an Adobe Reader extension, users can add GeoMarks – georeferenced markups – to which notes, photos, and a variety of other media can be attached.

To bridge the gap between the back office and the field, Gray & Pape implemented a TerraGo solution that included using TerraGo Publisher for ArcGIS to create custom GeoPDF maps and imagery, replacing the paper maps of the more typical workflow. The firm also used TerraGo Composer to assemble GeoPDF maps and reports into desired configurations. And, finally, the free TerraGo Toolbar enabled mobile researchers to record field data on the GeoPDF maps and export shapefiles with notes and markings to be integrated back into the GIS environment without the tedious and error-prone manual translation of the hand-written markups by the GIS analyst.

Historic Preservation During Infrastructure Planning

On a recent project that involved identifying historically significant structures to assist in future infrastructure planning, Gray & Pape field experts conducted 'windshield' surveys while traveling to many sites to observe and map locations of hundreds of historical buildings. See examples in ***Figures 1-2***. Each area of interest was identified using aerial and topographic maps that were converted to portable GeoPDF maps, which are easily opened in Adobe Reader in the field. After making referenced notations and marking sites on the GeoPDF maps, completed maps and field notes were sent back to Gray & Pape's GIS expert to import the data into ArcGIS. (For more information about mobile solutions, see ***Sidebar 1***.)

Gray & Pape noted that with a GPS device, mobile researchers would be provided only their current location, but often the point of interest was some distance away. The ability to place a GeoMark anywhere on the map enabled the creation of rich observations, which included digitized sketches of features of interest. Within GeoPDF maps, users with the free TerraGo Toolbar can

SIDEBAR 2

Increased Access to Imagery via Cloud

TerraGo and GeoEye recently partnered to enhance the access and use of digital imagery by enabling TerraGo's GeoPDF production capabilities in the next version of GeoEye's EyeQ platform.

The EyeQ platform is the first of its kind to feature on-the-fly GeoPDF production. EyeQ users are now able to produce and share interactive geo-referenced imagery products that are compact, portable and secure. GeoPDF images and maps can be easily updated and shared by mobile users such as first responders who may lack consistent access to robust communications services.

"The goals of GeoEye and TerraGo are the same – to make it easier to access, use and share valuable geospatial information across organizations and industries," said Tony Frazier, GeoEye senior vice president of Marketing. "This important partnership with TerraGo will bring our customers exciting new solutions, allowing an even greater return on their investments in high-resolution imagery and other advanced geospatial products from GeoEye." For more information visit www.geoeye.com or www.terragotech.com.

dynamically view latitude and longitude as the mouse cursor moves across the map, measure distances, make notes, draw shapes, attach images, and export these data for ArcGIS or other GIS systems with just a few clicks.

Another Gray & Pape project required layering historical maps over a project area map to help identify parcels or structures that have not changed for 150 years. This provided rich, dynamic GIS-like data presented in layers and easily studied by experts and non-experts alike to see how site snapshots evolve over time in a geospatial context. See examples in ***Figures 3-4***.

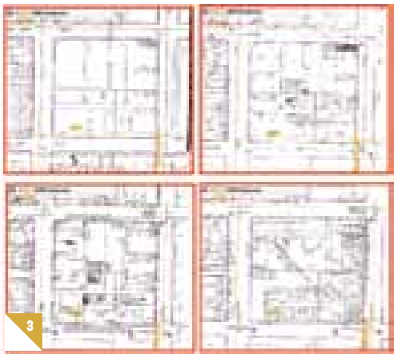
Using TerraGo software and GeoPDF files, Gray & Pape was able to implement an all-digital collaboration workflow. The firm condensed and simplified fairly complex GIS technology and got it out to the people in the field in a simple and straightforward package they could use.

For one project, Gray & Pape distributed more than 80 pages of GeoPDF maps, collected markups, and imported back into ArcGIS for a complete roundtrip of data. The maps showed aerial imagery and USGS topographic data. Field experts used TerraGo Toolbar to place a GeoMark for each historical building, cross-referencing field notes to a unique number assigned to each. The completed maps and field observations were electronically transmitted back to a GIS expert, who imported the GeoMarks into ArcGIS. This method of field verification eliminated manual transfer of data to ArcGIS, which saved time and improved accuracy.

In one major project over the last year, the firm had to create a planning tool for the evaluation of archaeological sensitivity across a large study area. Its investigators and a series of other consultants were tasked with evaluating multiple potential project routes within this area. There was a great deal of variability in GIS resources available to the various consultants – some were entirely without access to or expertise with GIS.

As such, Gray & Pape created a single GeoPDF product with the many layers of information affecting sensitivity, and distributed it across the project team. By simply creating a new copy of the GeoPDF map for each map revision, the firm could be certain that all parties were looking at the identical data.

In addition to supporting field data collection, TerraGo software has made sharing survey results easy. Gray & Pape can produce user-friendly GeoPDF map reports that enable a client to turn on and off multiple map layers and evaluate a project's cultural resources without using GIS software. All project participants can receive a robust GeoPDF map report on CD bundled with other deliverables. (TerraGo has the capability to deliver 'on the cloud' via its partnership with GeoEye. See ***Sidebar 2***.)



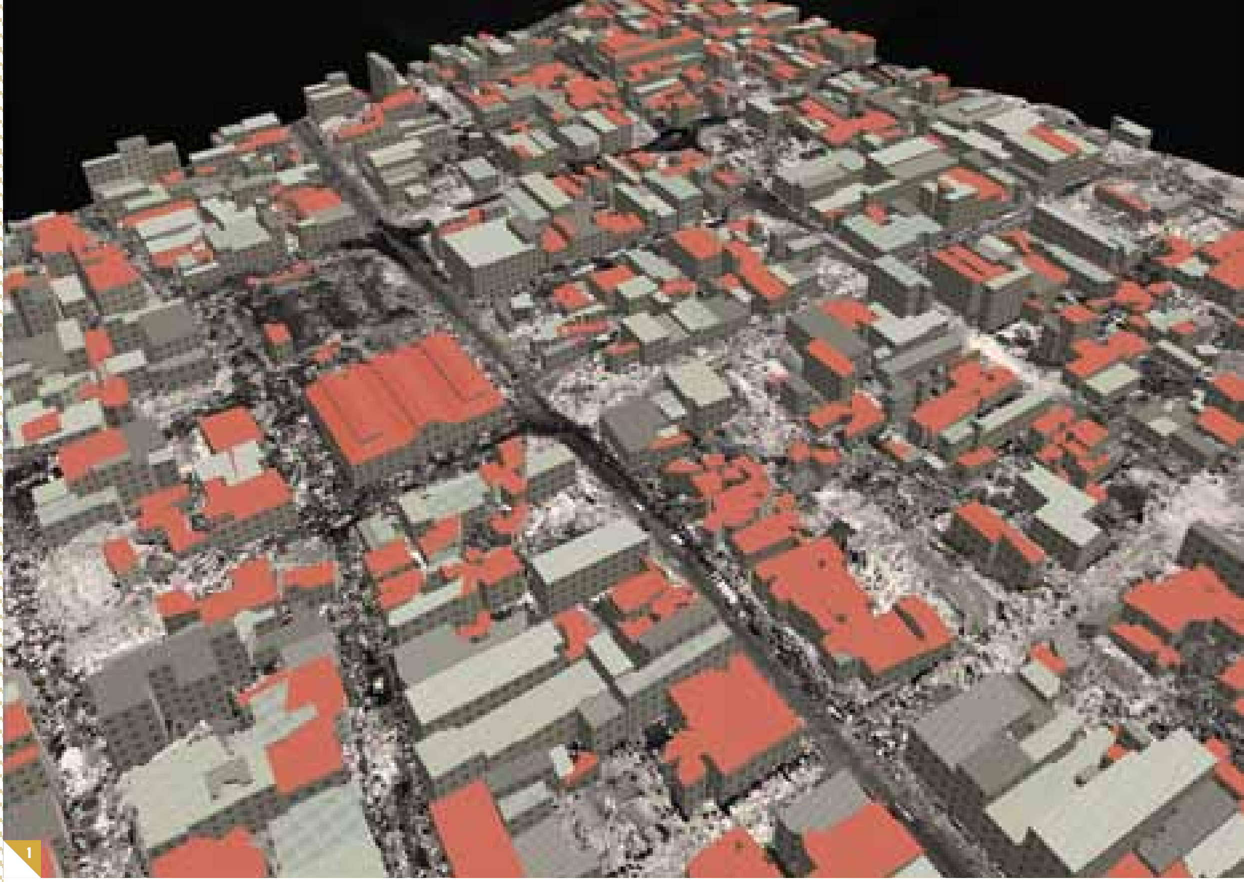
▲ **FIGURE 3.** *Snapshots from a GeoPDF created to support the identification of historic buildings and potential archaeological features. The four clips show historic Sanborn Insurance Company maps for a single block for a period covering roughly 60 years.*

▲ **FIGURE 4.** *This 1886 Sanborn Insurance Map, when overlaid on a current aerial photo, provides architects/historians with an important tool for determining the age of existing buildings. It also provides archaeologists with information on the potential location of building remains and buried features such as cisterns and privies.*

The right GIS solutions can help organizations like Gray & Pape to achieve a higher level of effectiveness and efficiency, and, in the specific case of Gray & Pape, ultimately to preserve and protect the treasures of our past.

Disaster Management

USING LIDAR



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TODAY, PROFESSIONALS ACROSS INDUSTRIES use geospatial data for up-to-date, accurate information about geographic areas of interest. Crucial information can be extracted from geospatial data using advanced analysis software to address challenges ranging from monitoring the effects of development to selecting optimal mining locations. Traditionally, most geospatial information has come from two-dimensional imagery and data. However, professionals involved in a variety of industries and applications (like disaster management) are increasingly utilizing three-dimensional sources of information (like LiDAR) to create photorealistic 3D visualizations, extract 3D features and export products to geospatial tools to help them understand the world around them.

▲ **FIGURE 1.** *Emergency responders can analyze LiDAR data in E3De software to extract 3D features and locate damaged structures or plan response efforts. Imagery and LiDAR data courtesy of the RIT Haiti Mission for the World Bank.*

Collecting LiDAR Data

LiDAR (Light Detection and Ranging) is a remote sensing technology that uses light pulses to measure the distance between a sensor and reflecting objects such as the earth's surface, buildings and trees. The result is a collection of data points called a 'point cloud' that is used to precisely render 3D shapes and accurately locate features in a scene. The accuracy of LiDAR technology has made it possible to map large areas with levels of detail that were previously possible only with time-consuming and expensive ground surveys. These benefits and others have led disaster management organizations to use LiDAR data as a source of information when mapping and making critical decisions.

The wide variety of applications for LiDAR data has resulted in the development of more advanced LiDAR sensors. These sensors have increased pulse rates that improve the quality and accuracy of their data. However, LiDAR datasets generated by these sensors are often so large that they can't be processed using traditional software methods. In order to effectively analyze large LiDAR datasets, users need a solution specifically designed to address this data format.

Advances in LiDAR Processing and Analysis

Because organizations involved in disaster management and other applications are now using LiDAR data more frequently to solve problems, there has been an increased demand for LiDAR processing and analysis software that can perform complex tasks like 3D feature extraction. This demand has led to powerful new LiDAR solutions, like E3De (from Exelis Visual Information Solutions, formerly ITT Visual Information Solutions), which can utilize large datasets to create realistic 3D visualizations, extract 3D features from a scene and produce 3D products and layers. Information extracted from LiDAR data using advanced technology can be included in geospatial analysis products for mapping fire fuels, creating forest inventories, monitoring vegetation encroachment and completing right-of-way analyses.

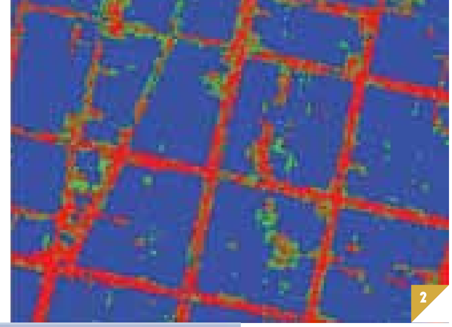
LiDAR data and geospatial imagery can be fused through a variety of software solutions that support both data types or, more commonly, that support the exported vector or raster results of LiDAR analysis. The benefit of fusing LiDAR data with geospatial imagery is the inclusion of accurate elevation and three-dimensional features in geospatial analyses or a GIS.

New LiDAR processing software streamlines the overall geospatial workflow by enabling users to export results to a variety of geospatial tools, such as ENVI image analysis software or the ArcGIS platform. In ENVI, users can fuse results with 2D data, such as multispectral and hyperspectral imagery, for further analyses or to create a variety of geospatial products. For example, a disaster management professional may want to fuse timely elevation information from LiDAR data with other geospatial imagery in ENVI to monitor changes in terrain related to volcanic activity. Similarly, advanced LiDAR processing software makes it easy to export results directly to the ArcGIS platform for mapping applications and additional decision making.

Advances in LiDAR processing and analysis software and sensor technology have led disaster management professionals to rely on LiDAR data for situational awareness and for critical decisions. Disaster response planning and management is one of the most significant applications of LiDAR data, when situational awareness and accurate decisions are vitally important. LiDAR use in this realm encompasses everything from mapping vegetation that is prone to wildfires, to creating an inventory of assets, to monitoring structural damage after earthquakes.

LiDAR for Disaster Management

Disaster management professionals look to LiDAR data and processing and analysis software to enhance their understanding of disaster scenes and to make critical decisions. Knowledge extracted from LiDAR data helps emergency responders efficiently plan disaster relief efforts to prevent property loss, reduce injuries, save lives and restore crucial utilities like water and electricity to affected communities.



Ideally, soon after a disaster, aircraft equipped with LiDAR sensors fly over affected areas to collect current data that is invaluable when planning an appropriate response. Once these data are processed, emergency responders use them for two main purposes: creating a visual map of the disaster area, and extracting important information about the area, such as determining safe locations for shelters, identifying downed power lines and locating areas that have a high risk of mudslides or flooding.

Visualizing Earthquake Damage

Emergency responders use advanced LiDAR processing software like E3De to visualize areas damaged by earthquakes. Gaining an accurate understanding of damage on the ground is paramount to an effective response. Creating 3D visualizations from LiDAR data helps emergency management teams detect and measure objects like collapsed buildings and standing structures. Because LiDAR data provides three-dimensional representations of manmade and natural objects, it is better suited than two-dimensional imagery for assessing damage to buildings and locating downed trees. The flatness of two-dimensional images makes it hard for viewers to identify areas of minor damage, whereas three-dimensional visualizations allow responders to get a more accurate, dynamic understanding of conditions on the ground. See ***Figure 1***.

The powerful, photorealistic 3D visualizations produced by advanced software like E3De make it easy to perform a quick visual analysis of an area to get an understanding of damage. E3De enables users to manipulate visualizations so that they can analyze an area from different perspectives. By being able to view an area from every angle, responders have a much better understanding of the scope of the disaster. Once they visualize buildings, debris, terrain and other features, they can determine where to focus their efforts and identify areas of interest that require further data analysis.

▲ **FIGURE 2.** *Emergency responders take results from E3De and export them to ENVI image analysis software, where they are fused with other image data to enhance road extraction efforts. Imagery and LiDAR data courtesy of the RIT Haiti Mission for the World Bank.*

▲ **FIGURE 3.** *Government officials exploit LiDAR data for disaster response planning and mitigation. The 3D viewer in E3De can be used to inventory assets such as buildings, roads and power lines. Imagery and LiDAR data courtesy of the RIT Haiti Mission for the World Bank.*

Analyzing Earthquake Damage

Once disaster responders have visualized LiDAR data, they hone in on areas that require further analysis in order to increase their understanding of the damage and plan response efforts according to the most urgent needs. One of the main ways emergency responders analyze LiDAR data is by extracting features.

After an earthquake, emergency responders might need to extract buildings, power lines, debris, roads and topography. This vital information helps them to target and ensure the efficiency of rescue efforts, such as identifying collapsed structures that have the potential for trapped citizens. To make this process as easy as possible, technology like E3De allows users to find and extract features of interest through an automated feature identification tool and to use quality assurance tools to manually edit and identify features as they explore the data in a 3D visualization. Users can perform feature identification on an entire point cloud scene, a defined subset of a scene or multiple files simultaneously.

Another way emergency responders identify features using LiDAR data is with their height. LiDAR data provides extremely accurate elevation information that enables users of image analysis software, like ENVI, to classify features by height. When setting up a classification, ENVI users could set road extraction at heights below 1 meter, debris extraction at a height of 1-3 meters, and structures still standing at 3 meters and above.

Because 3D feature extraction results often need to be refined to ensure that individual features are accurately identified, it is important to have a software solution that allows for easy editing of results. E3De allows users to fly through a photorealistic visualization and look for specific data points or individual features that need editing. They can also refine results to include individual features such as the shape of structures, the number of trees and the location of power poles. The ability to fix inaccuracies quickly during analysis makes it easier to make timely decisions.

Once emergency responders have extracted features from LiDAR data such as roads and debris, they can map an intact road network to support the routing of ground teams and supplies. The identification of these routes saves critical time and manpower during a disaster response. In addition to conducting a network analysis, emergency responders may also need to identify the best helicopter landing zones to drop off and collect people and supplies. Ideal helicopter landing zones are relatively free of debris and other vertical obstructions, and take into consideration an area's size, slope and proximity to targets; all of this can be done using LiDAR during a geospatial analysis.

Another way officials analyze LiDAR data for disaster response efforts is by comparing data collected over an area prior to a disaster with that collected afterwards. For example, emergency responders can compare before and after conditions of roof and structural components of buildings to assess damage. This work can be done visually in E3De or by exporting results to image analysis tools. Additional analyses made by emergency responders after a disaster utilizing LiDAR data include assessing areas that are flooded or could potentially flood, and looking for downed power lines or lines with potential hazards like encroaching trees.

Fusing LiDAR Data with Other Geospatial Data

Fusing LiDAR data with other geospatial data provides a more complete understanding of an area of interest. Data fusion combines two or more data modalities so that users can take advantage of the strengths of the different data types and have more information to make decisions. LiDAR data and geospatial imagery can be fused through a variety of software solutions that support both data types or, more commonly, that support the exported vector or raster results of LiDAR analysis. The benefit of fusing LiDAR data with geospatial imagery is the inclusion of accurate elevation and three-dimensional features in geospatial analyses or a GIS.

When professionals bring LiDAR products into advanced image analysis software like ENVI, they add more geospatial information to their analysis, which enhances their understanding of areas of interest. ENVI users can combine LiDAR data with other geospatial data and imagery to more accurately perform tasks like image classification, feature extraction, change detection and a variety of other image analysis techniques. For example, emergency responders take results from E3De and fuse them with other image data in ENVI to enhance road extraction efforts. They also take buildings' vector layers from E3De and overlay them on imagery to produce an inventory of buildings. This can be done with data gathered before and after a disaster to show which buildings have been damaged or destroyed due to the disaster. See ***Figure 2***.

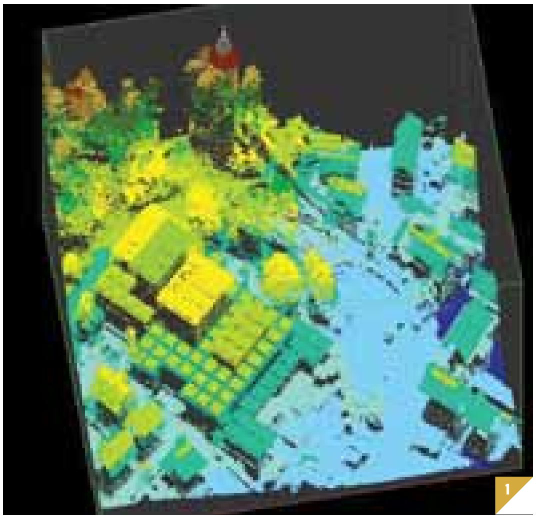
Similarly, disaster responders incorporate data extracted from LiDAR with other data in a GIS to inform important tasks. For example, responders export extracted debris and roads into ArcGIS Network Analyst to support ground team routing. Additionally, they can take topographic information extracted from LiDAR data and incorporate it in a GIS to determine flooding risks to disaster affected areas. Since responders use a GIS to map and coordinate plans of attack, it is important that all information, such as valuable LiDAR data, is included.

LiDAR for Disaster Planning and Mitigation

In addition to using LiDAR for disaster management, government officials also use LiDAR data for disaster response planning and mitigation. In this way, they use LiDAR to assess risks, reduce vulnerabilities and create appropriate action plans before disasters strike. For example, emergency management professionals use detailed elevation data from LiDAR to understand low-lying areas that are prone to flooding and to identify areas at risk for landslides and mudflows. Officials also create inventories of assets such as buildings, roads and power lines so that, if and when a disaster occurs, they are prepared. See ***Figure 3***.

LiDAR data provides critical geospatial information about areas of interest and is a valued complement to two-dimensional imagery and data. The accuracy of LiDAR data and the ability of advanced processing and analysis tools to visualize and extract important pieces of information have led to the adoption of LiDAR by professionals across industries. LiDAR technology is being used for more and more applications, but perhaps no application is more important than planning for disaster response or reacting after a disaster has struck.

EDITOR'S NOTE: Related stories on LiDAR in this issue include "QA/QC Challenges" on page 22 and "LiDAR Software Updates" on page 34.



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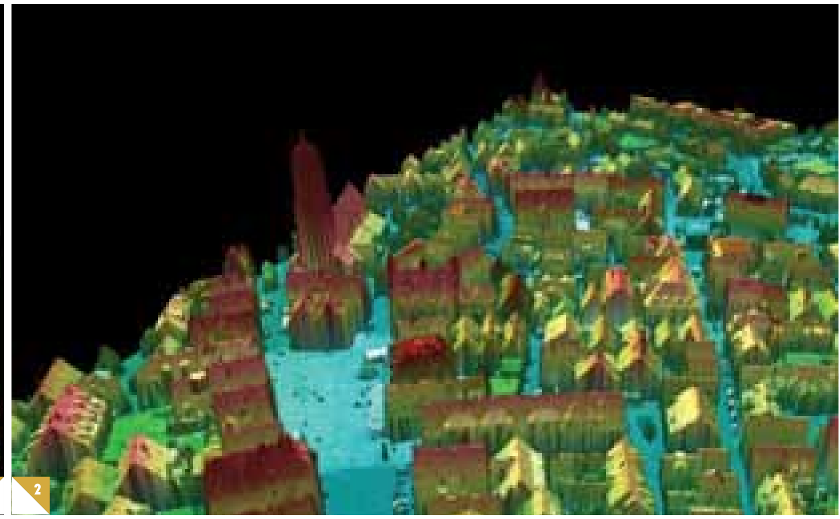

2

LiDAR Software Update

COMPANIES RESPOND TO CUSTOMER DEMANDS

THE MARKET FOR SOFTWARE TO MANAGE, PROCESS, FUSE, AND visualize LiDAR point cloud data is still very young and amorphous. As both the amounts of LiDAR data and the demand for it continue to grow, software vendors are developing innovative solutions to enable their clients to integrate this data into their workflows.

Large software developers (such as ESRI, Intergraph, and Autodesk) now support LiDAR natively in their software. Some manufacturers of laser scanners (such as Riegl, Leica Geosystems, and Optech) are expanding the functionalities of the software applications that they provide with their hardware, so as to try to keep their customers in their fold. Another manufacturer, Trimble, makes its integrated terrestrial solution available only in combination with its hardware, while it sells its airborne software to users without restrictions, because it wants to maintain the user base to which it has freely sold its eCognition and Inpho products. Some large users of LiDAR data such as GeoDigital and Merrick have developed their own in-house software, which they either keep proprietary (as in the case of GeoDigital) or sell (as in the case of Merrick's MARS software suite). Free, open-source LiDAR software, such as PDAL is also available.

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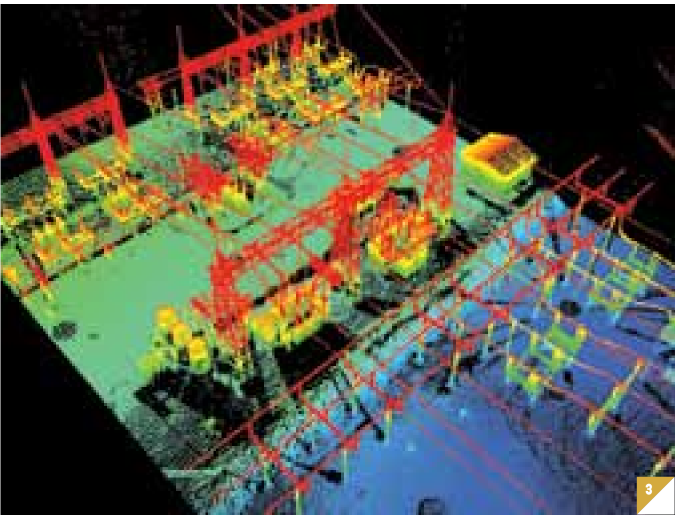
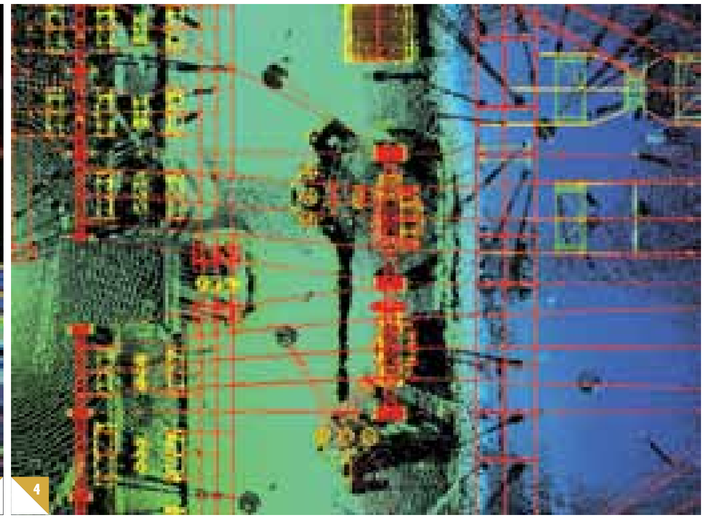
EDITOR'S NOTE: This is a comprehensive update on lidar software, with interviews of several key companies. For more information about the offering from Exelis (formerly ITT VIS), see page 30. For more information about LiDAR QA/QC, see page 22.

Current Market

LiDAR continues to grow in popularity, especially throughout the architecture, engineering, and construction world. The fact that all the major software vendors are now supporting it natively is clear evidence that it has become widely accepted. This is opening a much larger





market for LiDAR data and how it is being used, says Bill Emison, Senior Account Manager at Merrick. "Unfortunately, however, while there is great variety available, there is no consistency." In fact, the market for LiDAR software "is still an open game," says Michael P. Gerlek, an independent consultant with Flaxen Consulting. "There are many different players and they are trying many different things. LiDAR software now is at roughly the same development stage as software was for raster data 10-15 years ago."

"Hardware manufacturers," Gerlek explains, "are focusing on providing the specific software tools that they need for the data coming off of their devices, such as calibrating and corrections. Some of them are trying to provide additional pieces. Independent, third-party developers are going to develop more robust tools that work with post-processed data from different sensors. End users do the best that they can with the available tools, plus they develop their own."

In aerial LiDAR, which has been around much longer than ground-based LiDAR, users typically piece together applications and there are already many systems on the market. "Consolidation might happen for specific applications, such as corridor mapping, but there will always be a place for more open systems," says Gregor Willhauck, Software Product Line Manager for Trimble's GeoSpatial Division, where he manages a team of product managers for eCognition, Inpho and Trident Analyst. By contrast, he points out, in terrestrial LiDAR, there is more of a trend toward integrated solutions.

Some firms have increased their capabilities in this area through acquisitions. In 2010, Hexagon bought first ERDAS, which had developed its own LiDAR software tools, and then Intergraph. In October 2011, Autodesk bought Netherlands-based Alice Labs, which specializes in editing and displaying point cloud data. At the beginning of December 2011, GeoDigital, which specializes in the use of LiDAR for vegetation management and line rating and clearance analysis, acquired Powel, Inc., maker of a mobile work management product line that includes an application for managing utility field design, vegetation maintenance, outage recovery, and mapping. A notable exception to this trend is GIS giant Esri, which did not acquire a company specifically for LiDAR.

Not everybody, however, thinks that consolidation is the best way forward. "For managing, processing, and visualizing LiDAR data, I'd rather have separate packages, because that provides more flexibility," says Gerlek. "Software packages should focus on what they are good for,

◀ **FIGURE 1.** *Trimble Harrier Airborne laser scanning point cloud over the town of Biberach, Germany displayed in Inpho DTMaster, courtesy of Trimble.*

◀ **FIGURE 2.** *Trimble Harrier Airborne laser scanning data over the town of Biberach, Germany displayed as TIN surface in Inpho DTMaster, courtesy of Trimble.*

▲ **FIGURE 3.** *3D view of electrical substation outside of Denver, Colorado (colored by elevation), courtesy of Merrick.*

▲ **FIGURE 4.** *2D view of electrical substation outside of Denver, Colorado (colored by elevation), courtesy of Merrick.*

then stop." He points out that the available tools are, by and large, focused on specific types of analysis, such as feature extraction or linear and volumetric measurement, but there are few general software development kits (SDKs).

Formats and Standards

For the whole industry to grow, hardware manufacturers, software developers, and end users need interoperable formats. In the terrestrial market, the standards typically come from surveying and are more proprietary than in the aerial market, says Willhauck. The closest thing the industry has to a standard format is the LAS, a specification published, maintained, and copyrighted by the American Society for

◀ **FIGURE 5.** *An image generated in GeoDigital's VegWorks mobile work management software reflects asset and all related field data including poles, spans, maps, aerial photography, LiDAR mapping, customer information and work history. The application merges the data to allow a utility to quickly identify any right-of-way threats and to produce all work order details to dispatch crews for remediation.*

PDAL – The Evolution of an Open Source Option

Various tools have been developed to manage and manipulate LAS files. Howard Butler developed libLAS, a C/C++ library, for the Iowa Department of Natural Resources for use in its statewide LiDAR project and for general use. While libLAS is used for production purposes in the real world, explains independent consultant Michael Gerlek of Flaxen Consulting, it is limited to the LAS file format. He and Butler wanted a tool that could do more, such as provide a low-level file interchange capability and basic operations. So they developed PDAL as a successor to libLAS and as the 3D version of GDAL, another format with which they have also been involved and that has been around for years. Like libLAS, PDAL has received funding from the U.S. Army Corps of Engineers, which had additional requirements that called for a whole new library. "PDAL fills a market need that nobody else is filling, has no competitors, and is not competing against any product or company," says Gerlek. "We provide an underlying library on top of which others can build, if they need to do transformations or filtering pipelines."

Photogrammetry and Remote Sensing (ASPRS). Developed primarily for exchange of LIDAR point cloud data, the LAS is a public, binary file format for the interchange of any 3D point cloud data. However, according to Alastair Jenkins, President and CEO of GeoDigital, the LAS "has led to a massive war between companies to suit their own prejudices and advantages. The latest version still has a way to go."

"Companies that are end users of LiDAR data don't want to have to write their own file format support; they want that for free," argues Gerlek. "In general, having many different file formats out there incurs a development and maintenance burden on the vendor. Users need to be able to collect data with a sensor from one manufacturer, process it with software tools from a second manufacturer, and visualize it with software from a third one. Standards smooth out those transitions and allow different vendors to develop their own stuff and play together nicely. The days of closed, proprietary software are dead. The world no longer needs it. My former employer, LizardTech, is getting very little traction in the LiDAR space, in large part because the value of openness outweighs other possible feature advantages."

Challenges

As reported in previous articles on LiDAR in this magazine, the growth in data from LiDAR sensors continues to outpace the ability of users' software to manage it and process it. "That's not going to change any time soon," says Gerlek. Yet the ability to manage very large files is critical for production shops.

To deal with this challenge, heavy users of LiDAR data leverage GPU processing, compress and index data, and use 64-bit operating systems, which allow them to use more RAM and multiple CPUs. In particular, "quite a bit of research" is going into data indexing, says Emison.

Jenkins points out a different challenge: figuring out an efficient way to quality-control the data. "Five years ago," he says, "you could process 70 square kilometers in four hours and then you would spend 10 to 15 minutes doing QA/QC. Now you can process that data automatically in 10 to 15 minutes, but QA/QC will take you four hours. The real problem today is this: either you accept the errors or, if you need a certain degree of accuracy, you need to figure out an efficient way to do the QA/QC."

Future Trends

Gerlek predicts that ArcGIS, SOCET SET, MicroStation, etc., eventually will incorporate point clouds to the same degree that they currently support raster data. While some of these software products already have 3D support today, he points out, they are typically limited in functionality and cannot support very large models and analysis.

Will LiDAR follow the current trend toward cloud-based applications and data storage? "Since the majority of LiDAR data processing utilizes LAS (flat) files," says Emison, "I believe that the trend will support a migration from LAS files to relational databases (such as Oracle and SQL Server), then to cloud-based applications. With the pulse rate growing and the point densities rising, most organizations will have to develop a data storage system to handle massive amounts of data. Furthermore, as LiDAR becomes more popular, demand for this type of data will increase."

Trimble does not have any cloud/Web-based solutions, says Willhauck, but he sees "a trend toward it." He is not at liberty to comment on whether his company is currently developing any such solutions, but he points out that Trimble has other cloud-based businesses.

Going forward, most LiDAR software will continue to be specialized, Emison opines. "I don't see a single package but more software growing out of the verticals, not just a one-size-fits-all solution. I'd like to think ours would be that, but I don't think it will be the only game in town, the way Esri is for GIS."

A close look at Google Maps reveals many lines that do not connect properly. Whether that matters to users depends on their reason for using the system. For personal navigation, for example, it does not matter, but for engineering purposes it does. "Now there is a very broad spectrum of needs with regards to geographic accuracy," Jenkins points out. "The biggest trend you will see is a move to the creation of ultra-high density data and to processing on demand. For example, you can scan a complete oil refinery and use that data to make a completely new as-built, but a client who just wants to replace two pipes does not need that. If you have the model, you can make it easy for your clients to make changes. So, the operating principle should be scan everything, process as needed."

Much very promising research is being done with regard to fusing raster/vector data with 3D, but 3D will still be processed independently for the next couple of years, says Gerlek.

Trimble

Trimble has a complete land-mobile LiDAR solution, which is a combination of software and hardware, and an aerial LiDAR system that matches with its Inpho suite. "Because we have both air and land within the same division, we are working to apply the same solutions to both, to navigate and store point clouds," says Willhauck. "These solutions also extend into Trimble's other divisions."

Trimble has a strong focus on automating the process of feature extraction. While the Inpho suite has a strong offering of LiDAR filtering algorithms (developed in cooperation with the University of Vienna), eCognition provides state-of-the-art object-based feature extraction capabilities. Between the two software packages, the complete LiDAR workflow from data processing and filtering to feature extraction is covered. All of Trimble's LiDAR systems come with an optical component: an on-board camera that offers a quick solution to colorizing point clouds. This combination benefits automatic feature extraction and enables eCognition to combine LiDAR data and raster imagery into a GIS. See ***Figures 1-2***.

Merrick

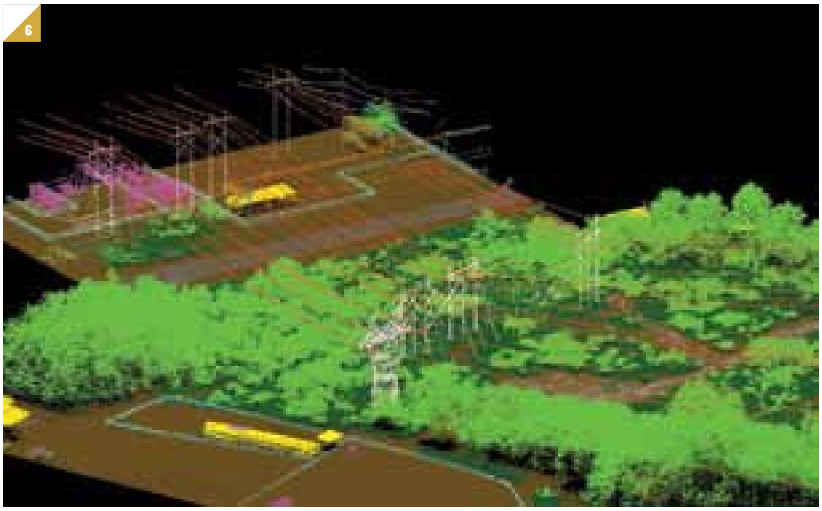
Merrick is an engineering firm and its geospatial group is responsible for collecting LiDAR data, processing it, and producing derivative products. "Since we've been in the collection game for about a decade, we decided to build our own system," says Emison. "That is why we developed MARS and use it through our entire workflow process. We do use other software, most notably ESRI and some imagery products for ortho photos. We also offer MARS commercially – mostly for those who need basic tools to manage and visualize data, chop it up, re-project it, etc. – and offer training. Our goal is not to be a major software vendor but to use it, enhance it as needed, and sell it as we can."

According to Emison, MARS is focused mostly on production, while Esri's software is focused on end users. "We build software for people who need to manage LiDAR data, while they build software for those who just need to use it and analyze it. We are building vertical applications that support different industries, such as mapping power lines for vegetation clearance safety analysis or mapping obstructions of in/out-bound airport paths, as well as more specialized packages for forestry, hydro-modeling, etc." See ***Figures 3-4***.

GeoDigital

GeoDigital is a LiDAR acquisition company that specializes in corridor mapping, using engineering-grade systems

▼ **FIGURE 6.** ***GeoDigital's stabilized airborne and terrestrial remote sensing systems are able to acquire base map data to produce three-dimensional images of right-of-way and structures. They combine traditional corridor imagery and asset mapping technologies with a cost-effective LiDAR to survey the transmission line for clearance problems, danger vegetation and abnormal geometry, while providing access to engineering survey grade LiDAR when needed.***



"The biggest trend you will see is a move to the creation of ultra-high density data and to processing on demand. For example, you can scan a complete oil refinery... but a client who just wants to replace two pipes does not need that... So, the operating principle should be scan everything, process as needed."

– Alastair Jenkins of GeoDigital

mounted on helicopters, fixed-wing aircraft, and land vehicles. It produces 3D models, with an absolute vertical accuracy of less than 10 centimeters and a horizontal accuracy of less than 15 centimeters, which organizations can use to map, assess, and understand their assets. "We are scanning 7,000 miles of power lines per month, which used to be a year's capacity for a large firm," says Jenkins. "Our internal software group doubled in size when we acquired Powell."

"We use data from an inertial measurement unit (IMU) and a GPS receiver to determine the collection platform's position in space and its orientation; we then combine that data with the range to the target to determine the polar coordinates of each return. This is the hardest step to do very accurately. If you don't start off with good data, it never gets better." There are commercial off-the-shelf solutions to process the inertial and GPS data, such as Applanix' POS product line. "We have done very significant writing of our own software, to achieve higher accuracy, make a very accurate point cloud, and fuse it with imagery. We don't sell it because it is part of our core offering."

GeoDigital's primary visualization tool is its Grid Intel Online (GIO) Web application, which allows its clients to access billions of points on demand, via a product like Google Earth. They can draw a box around their area of interest and download the point cloud for that area. "Our strength is that we provide our software in the form of a viewing tool, which is customized for handling massive amounts of data and allows such functions as zooming," says Jenkins. "Our focus is to make that data available faster and faster."

When it bought Powell earlier this Winter, GeoDigital turned it into a new software and analytics division, GeoDigital Solutions, Inc., with responsibility for software development and the integration of complementary technologies into turnkey enterprise solutions for utilities and other asset-intensive industries, including rail, oil and gas, transportation, and telecommunications.

"We transform LiDAR data into something that is useful for a utility," says Scott Rogers, the division's President. "We have been building tools for the utility industry for about 15 years. We provide field tools to identify features, document them with a quick user interface, and report back to the rest of the organization. This is very important for meeting regulatory requirements. We turn LiDAR data into actionable information and assure that the work has been completed. Our software can generate a cost estimate and feed back-end systems. We are selling both the software and the service, depending on our clients' needs." See ***Figures 5-6***.

Esri

Esri has been working with LiDAR data for many years and has partners that process it. In the past, LiDAR data has been used mainly for elevation, explains Steve Snow, Esri Marketing Specialist. Users imported LiDAR data into a geodatabase and then built terrain datasets. "With ArcGIS 10.1, users will be able to directly read LAS files through the new LAS Dataset. They will be able to render LiDAR data on the fly as a surface or as a point cloud."

Esri's 3D team developed these capabilities in house. This year, the company will provide a series of free LiDAR workshops around the country. "We are doing this to support decision makers," says Snow. "They want faster access to the information via GIS, so that they can make timely and accurate decisions. A point cloud has no value until you extract the information from it. All geospatial software is moving to 3D. It is now an expectation."

Microsoft

Point clouds are no longer restricted to LiDAR. Around the middle of 2012, Microsoft's Vexcel Imaging division, which manufactures digital aerial cameras, plans to release software that generates point clouds by using overlapping aerial images. "We are still in the development phase and only run the software on development machines," says Alexander Wiechert, the division's business director. "We fly an area with our UltraCam, firing it extremely fast, and get highly overlapped aerial images. Then we do dense matching of each pixel. We achieve much higher point densities than with LiDAR. It is a new trend, but we have a lot of relevant experience modeling cities."

Software vendors, end users, and academics are developing new tools to manage and process LiDAR point cloud data. While it is too early to know whether any one particular software packet will dominate the market in a few years, it is clear that LiDAR data will soon be as standard and indispensable a tool for geospatial analysis as raster data is today. Additionally, the availability of vast amounts of point cloud data is greatly boosting the development of 3D modeling software.

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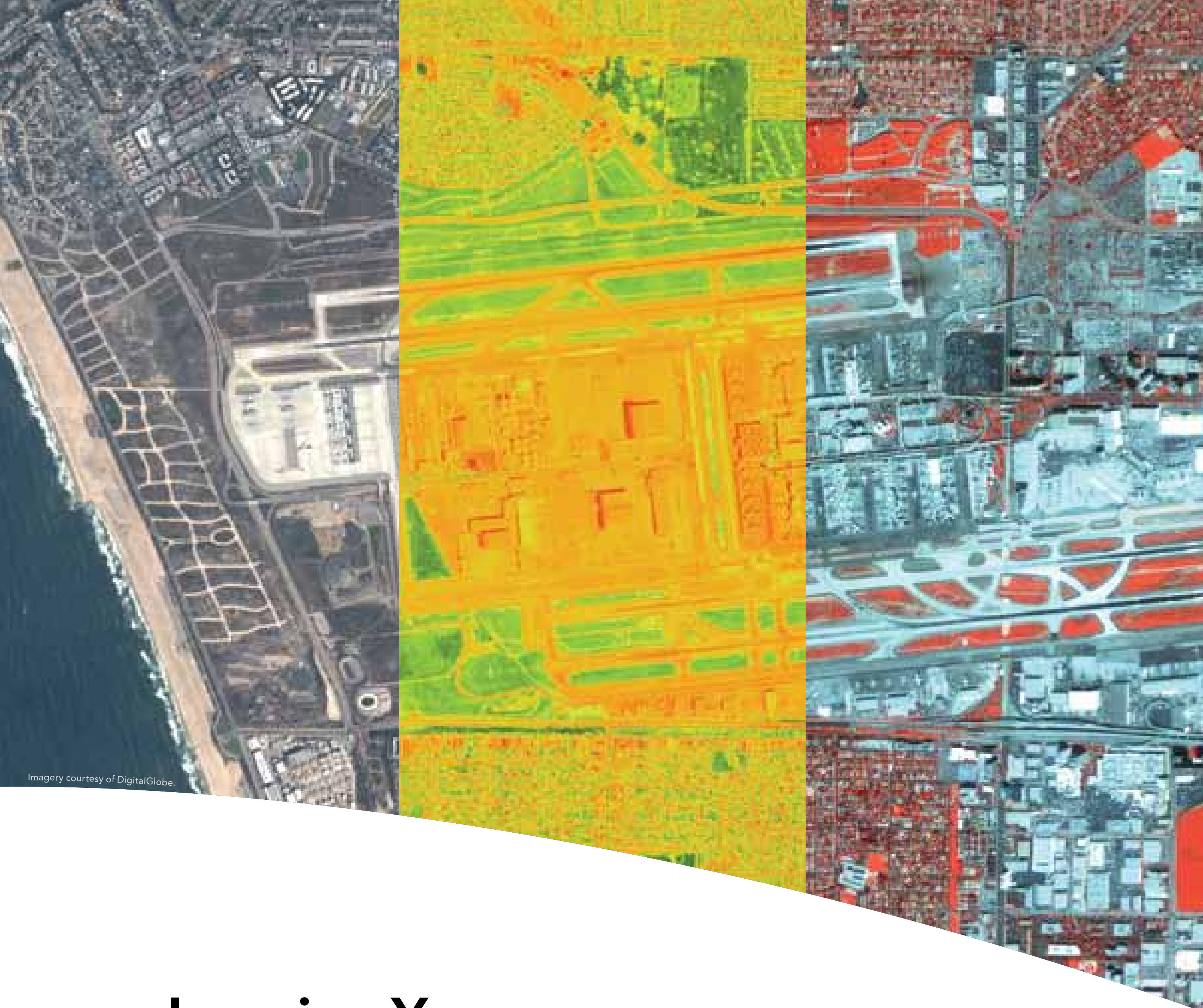

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