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S P A T I A L

ELEVATING GLOBAL AWARENESS

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“We are interested in bringing whatever assets there are together to answer society’s problems.”

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“Data Democracy is grounded in the belief that this would be a *better world* if more decisions were informed by space-based Earth observation data.”

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Colorado wildfire image taken June 13, 2013, courtesy of DigitalGlobe. See details on page 6.

APOGEO^o

S P A T I A L

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

APOGEO PROVIDES VISUAL INTELLIGENCE elevating global awareness for the long-term sustainability of the planet and people. Business, government and academic professionals find here the information—and inspiration—for using geospatial tools to build a more sustainable world. With the fresh, relevant insights from expert contributors, stunning visuals and clear examples of the technologies, those who make critical business and policy decisions about the world's resources will understand the visual power of remotely sensed data.



It is exciting to see the launch of *Apogeo Spatial* and its focus on ecosystem health. Our ecological and social challenges are intertwined and global. Utilizing the view from space will assist us in addressing large-scale ecosystems health and in determining the actions that will be generative and effective in healing the planet. *Apogeo Spatial* is bringing critical ideas and tactics for utilizing geospatial tools to solve global issues.

Anita M. Burke
Founder / The Catalyst Institute

Apogeo Spatial is an important link to the education and academic communities to show young people the impact of geospatial technologies in helping to solve challenging problems facing humankind and to know more about the unknowns.

Mark Brender
Director / DigitalGlobe Foundation

The *Apogeo Spatial* launch is very exciting for those of us working in the geospatial field. *Apogeo* will be the leading source for understanding how global-scale issues can be addressed using geospatial information and tools.

Combined with its partners in the Location Media Alliance, it becomes a primary means to keep up with the revolution in spatial information.

Bill Gail, PhD
CTO / Global Weather Corporation

Apogeo is providing game-changing insights for a game-changing sector.

Nancy Colleton
President / Institute for Global Environmental Strategies
Executive Director / Alliance for Earth Observations

An intricate maze of small lakes and waterways defines the Yukon Delta at the confluence of Alaska's Yukon and Kuskokwim Rivers with the frigid Bering Sea. Wildlife abounds on the delta and offshore, where sheets of sea ice form during the coldest months of the year. ASTER image taken Jan. 1, 1999. Image courtesy of U.S. Geological Survey, Earth Resources Observation and Science Center.

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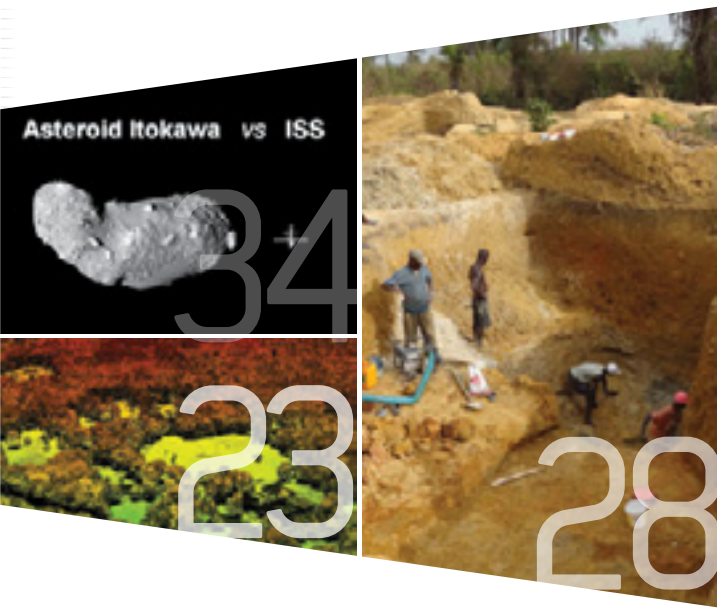
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Colorado Fires

SUMMERS IN COLORADO are unfortunately known for wildfires, and the last few years have resulted in extensive loss of property, including many homes.

This image was taken on June 13, 2013, just days prior to this issue going to press. At this time, two lives and 502 homes have been lost, the highest number in Colorado state history. It shows smoke and fires still burning, along with burnt areas where it's dark. The red areas are actually green vegetation, shown in color infrared.

Our feature story on using geospatial tools for wildfire detection, response and recovery appears on page 23. The image shows Black Forest, Colorado, which is 15 miles northeast of Colorado Springs (Lat: 39.02399, Long: -104.68857).

Image courtesy of DigitalGlobe. 

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[Summer 2013 / Vol. 28 / No. 3]

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

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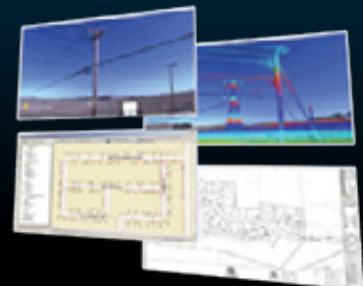
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Apogeo Focuses on Fire, Wind and Asteroids

DEAR COLLEAGUES AND READERS,

Thank you for reading *Apogeo Spatial*! I am full of gratitude for your participation, whether it's as a reader, a contributor, a company that invests with advertising, or any advocate of Earth observations. We are so fortunate to work in a field where our efforts make a tangible difference in many ways and to all our lives every day.

Earlier this year, we introduced our strategic alliance of geospatial publications, the Location Media Alliance (LMA; www.locationalliance.net). We have quarterly editorial themes that we address in each of our five publications (*Apogeo*, *Sensors & Systems*, *Informed Infrastructure*, *LBx Journal*, and *Asian Surveying & Mapping*). The current theme is energy.

In this issue, we cover energy with a story about wind farm siting beginning on page 38. Over a decade ago, I told my dad, a farmer in Kansas, that we should invest in wind energy out there on the plains. We lived for a time on his father's farm, complete with an old non-functioning windmill and well house (see photos). Growing up, I heard about crop prices, dependence on the weather, and the importance of water. Dad sold the farm water rights from the Ogallala Aquifer to my hometown, Hoxie. These aquifers around the world are being drained and stressed. Some estimates indicate that we have as little as 25 years left relying on this source of water. (Our Spring theme was water; read about water sensors by downloading it here: www.apogeospatial.com.)

While wind is a positive factor for energy generation, it can turn negative around wildfires, such as we are experiencing now in many places around the world, and in Colorado, where I live now. We've lost more homes (502 and counting) than in any fire before in state history. I cannot imagine the loss these people must feel.

Our feature story on using geospatial tools for wildfire detection, response and recovery appears on page 23. The article notes how researchers are determining how bark beetle infestation affects fire danger. Over the past decade throughout the Mountain West, warmer winters have allowed

the bark beetles to survive through the winter, upsetting the equilibrium and causing the death of millions of pine trees. Thus, climate change has helped put the trees at great risk, and exacerbated wildfire risk. This is an example of the ecosystem having no boundaries.

Also in this issue, Matt Ball of *Sensors & Systems* interviews Barbara Ryan, Director of the Group on Earth Observations Secretariat, who echoes my sentiment from the Spring issue that there are no boundaries from space. She addresses it this way, in her interview on page 14:

"Most of the information that GEO is interested in transcends national boundaries. Atmospheric, oceanic and many terrestrial processes do not respect national boundaries, and actions in one part of the world often have wide-spread consequences."

I want to thank the Secure World Foundation and the Alliance for Earth Observations for their continued support. I also want to thank Dr. Ray Williamson, editor, and our Editorial Board, most of whom have been with us for the past nine years, since I took over the magazine: Mark Brender of DigitalGlobe, Anita Burke of The Catalyst Institute, Nancy Colleton of The Institute for Global Environmental Strategies, Dr. Bill Gail of Global Weather Corp., Anne Hale Miglarese of PLANETiQ, Dr. Hans-Peter Plag of Old Dominion University, and Kevin Pomfret, Esq., of The Centre for Spatial Law and Policy.

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Warmly,

Myrna James Yoo, Publisher



Myrna James Yoo

Publisher and
Managing Editor
Apogeo
(formerly *Imaging Notes*)
and *LBx Journal*

Co-founder
Location Media Alliance

Owner
BlueLine Publishing LLC



James Farmhouse
with windmill and
well house, circa
1975.



Juxtaposition of
new and old: wind
farm and windmill
together north
of I-70, north of
Ellsworth, Kansas.
Photo credit: Jim
Glynn.



Tiffany Chow

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www.swfound.org

Data Democracy

PROGRESS, BUT MORE TO BE DONE

WHAT IS DATA DEMOCRACY? The Committee on Earth Observation Satellites (CEOS) Working Group on Capacity Building and Data Democracy (WGCapD) was reconstituted in 2011 around this concept. It was first introduced as an idea in 2008 during South Africa's chairmanship of CEOS and further developed in subsequent years under the CEOS leadership of Thailand and then Brazil.

The Data Democracy initiative stands on four pillars:

1. **Data Access**
2. **Data Dissemination**
3. **Sharing of Software Tools**
4. **Training and Education**

As the four pillars indicate, this concept is not only about widening access to space-derived Earth observation (EO) data. Data Democracy is just as much about improving the efficacy of delivering data to end users, proliferating software tools that will enhance the translation of that data into meaningful information, and tangibly developing the capacity of data users around the world to interpret and use data in their daily decision making.

Fundamentally, Data Democracy is grounded in the belief that this would be a better world if more decisions were informed by space-based EO data, and thus, we are all best-served by ensuring that data are available, accessible, and interpretable by decision makers all around the world.

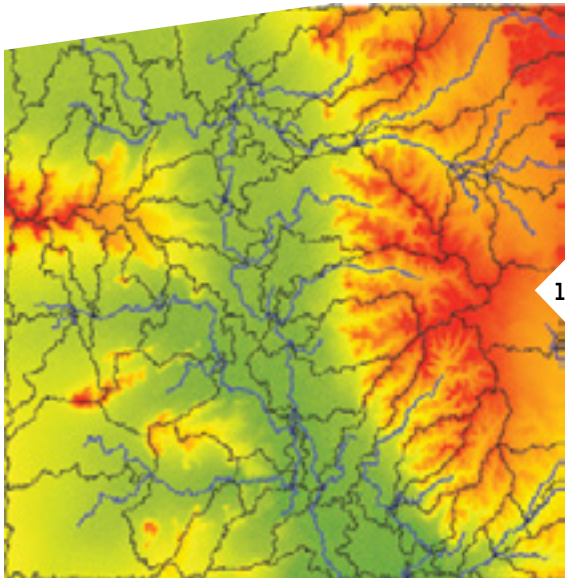
CEOS WGCapD was reconstituted around these principles. The working group is proceeding in two main ways: establishing effective coordination and partnership among those players committed to Data Democracy and working toward improved data accessibility, particularly in underserved communities.

Secure World Foundation (SWF) has been

involved in WGCapD since its reconstitution two years ago, thanks largely to its partnership with the U.S. National Oceanic and Atmospheric Administration (NOAA), current vice-chair of the working group. Recently, SWF co-hosted a weeklong workshop in Nairobi, Kenya, at the Regional Centre for Mapping of Resources for Development (RCMRD). Other workshop hosts included the Brazilian National Institute for Space Research (INPE), the South African National Space Agency (SANS), NOAA, the U.S. Geological Survey (USGS), the U.S. Agency for International Development (USAID) and the National Aeronautics and Space Administration (NASA) SERVIR program.

The workshop brought together 12 participants from East African countries to discuss digital elevation models (DEMs), to train on a wide range of hydrological modeling software (most of which was open source), and to deliver newly-released 30-meter data from the Shuttle Radar Topography Mission (SRTM). It was inspired by an opportunity to share new and useful data with end users. For those countries particularly prone to flash floods, the data can enable decision makers to better predict and respond to these devastating natural disasters. This truly international, collaborative effort was a very tangible expression of the principles of Data Democracy and the WGCapD goals.

Nevertheless, one major element was missing for this capacity-building effort to be considered



participants realized the potential of the data and associated software tools on which they were being trained. I also had to field questions from all of the non-Somali and non-South Sudanese participants wondering when they might receive the 30-m data for their own countries. As it turns out, “red tape” is a universal affliction and most participants were satisfied knowing that the U.S. agencies involved were supportive of the release, but were still working through bureaucratic hurdles.

◀ **FIGURE 1.** Watersheds (in black) and drainage (in blue) from SRTM30. In colors from green to red, green starts from 150 meters high, to reds at 397 meters high.

an unequivocal success. Not all of the participating East African countries were able to receive the 30-m data, which are widely regarded as the most comprehensive and highest quality elevation data currently available, but it is only publicly available for the continental United States. Since the SRTM mission in 2000, the U.S. National Geospatial-Intelligence Agency (NGA) has kept much of the raw data out of the public realm, but seeing the importance of the humanitarian and sustainable development applications of the data, NGA has recently opted to release some of the 30-m data and is considering releasing additional data in the near future.

Personally, there were two main takeaways from this experience. First, I feel so fortunate to be working for SWF and with the other WGCapD members toward the Data Democracy goal. I would venture to say that the EO community has come a long way in pursuing these principles, in freeing up satellite EO data and sharing expertise so that maximum benefits can be derived from them. There are many who would never believe that a national intelligence agency would go to such great lengths to share data purely for humanitarian purposes.

▼ **FIGURE 2.** 3D view of Landsat 5 image (TM sensor - color composition: Band 5 in red, Band 4 in green, and Band 3 in blue. Image acquisition date Dec. 29, 2010, on SRTM90.

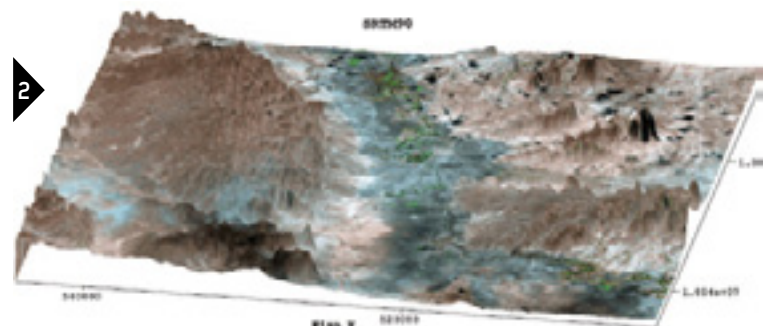
NGA has been working with NOAA, as the DEM project lead, to release the 30-m data through the WGCapD. The prospect of a wider release was a major driver for the first workshop in what all hope will be a series. The WGCapD was able to deliver the SRTM 30-m data to participants from South Sudan and Somalia at the Nairobi workshop.

Second, while we have made significant progress, more can and should be done in the realm of Data Democracy. This project needs to be seen to completion, for example. There are at least a handful of countries in East Africa patiently awaiting 30-m data that they now have the training and tools to use—not to mention that WGCapD would like to replicate the experience in other regions and underserved communities around the world.

Unfortunately, because of the time-intensive coordination across multiple U.S. agencies on the release of the data, some of the participants left without data for their respective countries. While the participants agreed wholeheartedly that the training they received during the weeklong workshop was beneficial, what they really wanted was to return to their countries and their day jobs with the higher resolution elevation data in hand.

Further still, there is an opportunity to follow suit with more advanced elevation data. WGCapD is an ideal forum through which other countries and government agencies can make data more accessible for humanitarian purposes. Finally, we can all continue working toward a future where the principles of Data Democracy are taken as a given, rather than a new way of doing business that cannot be achieved without challenging bureaucratic hurdles. ∆

I had the opportunity to be personally involved in this workshop from inception to completion. I was fortunate to observe firsthand as the



Location Data Privacy Guidelines Released

THE LOCATION FORUM



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THE LOCATION FORUM'S PRIVACY COUNCIL recently released *Location Data Privacy: Guidelines, Assessment & Recommendations*. These groundbreaking guidelines represent the first industry-created set of best practices for improving how location data is gathered, used and managed, along with a 'scorecard' for quantitatively measuring a company's privacy risk level.

"Much like financial and healthcare records, location data can reveal an enormous amount of personal and sensitive information about an individual," explained Natasha Léger, President, The Location Forum and Editor, *LBx Journal*. "These guidelines

enable users and companies to understand the value of the information so that they can both take the appropriate measures to safeguard what type of data is disclosed, and determine how it is used and shared."

Location-based services and applications have become more than a technology or feature; they are an integral part of our lives. People define themselves not just by who they are, but where they are.

Location data is now everywhere, easily accessible, and collected at an unprecedented scale. In the Information Economy we live in, personal data and similar forms of information are the new currencies. Location data is the universal link between all data, because everything and everyone is somewhere.

For businesses, location information can transform virtually every facet of an enterprise from operations to sales and marketing, customer care and even product development—all with a goal of having a positive impact on the bottom line. It is therefore rapidly becoming the newest "information weapon" used by CIOs, CMOs, COOs and digital strategists to gain a competitive advantage.

The problem with location data today is that it changes as it weaves through various hands—applications, vendors, developers, government,

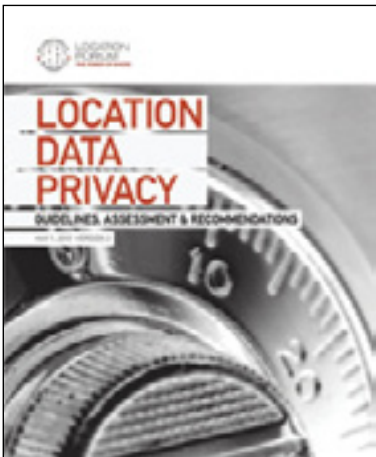
companies, data providers, and individual users. Another complication is the diversity of legal protections across countries and states that make developing a consistent privacy policy a moving target. All this is set against a business atmosphere of continuous pressure to develop innovative location-based products and services.

The power, benefits, and also the risks associated with location data are in its capacity to infer more personally identifiable information than the face value of the original information. While consumers and businesses are deriving great value from location-based services, targeted advertising and other applications, significant questions persist around location data privacy. In particular, how is location data being shared, who has access to it, and who controls it?

The Location Data Privacy Guidelines were developed for those on the front lines of location data product and services development, as well as those who hold corporate, legal or fiduciary responsibilities. They bring attention to issues that many organizations and companies have chosen to ignore, due to lack of legal certainty around requirements, and provide a framework of location data practices for developers, managers, marketers, and executives.

The guidelines define location data broadly. If you are a geospatial professional, you need to read these guidelines and take the Location Data Privacy Risk and Transparency Assessment to determine if your location data management practices pose any potential privacy risks.

You can download the guidelines at www.thelocationforum.org/privacy. 



FOLLOWING ARE THE TOP TEN NEWS STORIES for each month prior to this issue as recorded via visitor views to the daily updates on *Sensors & Systems* (www.sensorsandsystems.com). The stories at the top received the most views for the month. Type in the short URL to access each story or access all here: <http://bit.ly/11v40as>

MAY	MAY
<p>■ Harvard Researchers Publish Satellite Imagery-Based History of Conflict in Sudan http://bit.ly/16aaTkv</p>	<p>■ RapidEye Delivers Images of Floods in Germany http://bit.ly/19cuS3R</p>
<p>■ New Public Application of Landsat Images Released http://bit.ly/10oRk9D</p>	<p>■ Satellite Imagery Helps Study Tropical Tree Cover and Climate Change http://bit.ly/ZWfR3F http://bit.ly/12BVRWp</p>
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Barbara Ryan
Director
GEO Secretariat

GEO Update

Broader Outreach is Priority



The Group on Earth Observations (GEO) is working to build the Global Earth Observation System of Systems (GEOSS) by coordinating collaborative capacity across member nations. *Sensors & Systems* (S&S) editor Matt Ball spoke with Barbara J. Ryan, Director of the GEO Secretariat, at the recent Geospatial World Forum in Rotterdam. The conversation covered the mission and outlook for the group, as well as a new directive for broader outreach to the public and the private sector.

S&S *We first met when you were at the U.S. Geological Survey (USGS) and were promoting The National Map. What has been your path to the international role as secretariat director at GEO?*

RYAN Well, I joined the USGS right out of college and never did I expect to spend the majority of my career (34 years) there. It was during my last eight years there, 2000-2008, that I was associate director for geography. In that capacity, I managed remote sensing, the topographic mapping program (*The National Map*), and the USGS geographic analysis and monitoring research functions.

While *The National Map* had a domestic focus, we would interact internationally, much

like this meeting, with other national mapping agencies around the world to see their technological and policy developments. We were all facing the same challenges, primarily how to move all this information from paper into a digital arena, and how to share the information more broadly.

The remote sensing part of the job also allowed us to establish international partnerships, largely based on the Landsat program. When the USGS assumed flight operational responsibilities for Landsat back in 1999, with NASA building and launching the satellites, and the USGS handling operations for Landsats 5 and 7, we became a full member on the Committee on Earth Observation Satellites (CEOS). It was several years later that CEOS stepped up to become the space coordination arm of GEO. So, that's generally how I became familiar with GEO, and then about five years later I moved into the director's position here.

S&S *Is the primary goal of GEO around monitoring global change?*

RYAN The primary goal is the assurance of Earth observations so that we can address society's environmental problems. While many of our activities are targeted toward monitoring global change, we're actually more concerned about the assurance, continuity, sustainability and interoperability of observing systems, so that monitoring across multiple domains can be done. Governments, research organizations and others actually do the monitoring. We just want to make sure that the assets are in place, and that the data from these monitoring efforts is shared broadly. One of GEO's primary objectives is to advocate broad, open data sharing, particularly if the data was collected at taxpayer expense—the citizens of the world should have access to that information.

S&S *So, addressing gaps in Earth observation is part of the mission, along with cataloging what is in place and knowing what is planned?*

RYAN Yes, there are several targeted gaps in observing systems, either temporal or spatial gaps in key datasets, as well as inadequate access to information in different areas of the world.

S&S *One of the things that has fascinated me about the history of Landsat is the ongoing need to get data back from ground stations around the world in order to create an archive. Because, given its longevity, there simply wasn't the technology to archive all the information centrally when the program began.*

RYAN Yes, you are right, and that's actually an interesting story because the on-board capabilities were not robust enough with the early satellites to have on-board storage recorders. The program had to use international ground stations to download data so that storage space for the next collect could be made available.

S&S *One observation approach that I'm really excited about is the National Science Foundation (NSF) National Ecological Observatory Network (NEON) that incorporates both ground-based and aerial observation, with a view toward a 30-year consistent record to understand climate change.*

RYAN NEON was just getting its start when I left the USGS, and we are now working at GEO to strengthen our relationship with the National Science Foundation (NSF) in the U.S., and similar organizations around the world. From a U.S. perspective, the federal agencies that are most involved in GEO are NOAA, NASA, USGS, the EPA, the Smithsonian, and increasingly the U.S. Department of Agriculture.

A best practice here in Europe that we are trying to encourage globally is that of the European Commission's Framework Programme. The Commission earmarks research, science and technology resources for GEOSS implementation. So, the calls for

We worked on an interoperability arrangement between GEOSS and the WIS resulting in data from one system being discovered by the other system. We are now hearing, particularly from some members in the developing world, that they are getting access to information that they didn't know existed.

So, while the United States needed those ground stations around the world to store data, the funny thing about the approach is that it built an international network that has survived and actually thrived over the last 40 years. I am convinced that the reason Landsat is so popular and used more around the world than almost any other satellite is because of the roots of the international ground station network.

While the USGS continues to interact with the international ground stations to ensure a copy of all the historic data is stored in the USGS archive, I think there's still a fair amount that is not back in a centralized archive, so that effort is ongoing.

proposals that go out to European researchers request that the proposers articulate how their project will advance GEOSS implementation. It has been a good way of advancing GEO goals through the European Commission, and we would love to see the same kind of agreement with the research funding agencies of China, Japan, the United States, and many others.

S&S *I was excited to see that the European Space Agency (ESA) selected the biomass mission as the next satellite to be developed to better understand the Earth. The peer review of Earth Explorer missions seems a novel approach to prioritize and define the next Earth observation missions.*

RYAN We've started to hear from some of the other communities about missions that they would have liked to see funded... What I find interesting about the approach is that more users are becoming engaged in the process. In many instances, science, cadastal and space agencies are about pushing information out to potential users. We are trying to create more of a pull for this information – transitioning from a supply-driven to a demand-driven approach. Actions like the ESA peer review process start to create a demand-driven process as compared to a supply-driven approach, ultimately resulting in a prioritization of user needs.

Global transparency will help create more stability and a more food-secure world.

S&S *I like the fact that in a constrained economic time, it still values those that define missions, and doesn't dismiss outright, but prioritizes funding. With Europe's Copernicus program (that used to be known as the Global Monitoring for Environment and Security, GMES), that's another exciting effort that fills in gaps and takes a world-leading Earth observation approach.*

RYAN When one looks at the Copernicus Sentinel series of satellites, there is a tremendous opportunity, in collaboration with the Landsat series of satellites, to have more frequent global coverage of the Earth's land masses. In other words, when you have two Landsat satellites, you get a recurrence interval every eight days, but with the Sentinel Series in the 2016 or 2018 time-frame, you could get a recurrence interval every three days. With that frequency, one could start routinely monitoring crops from space, and not just one or two collections during the growing season, but weekly observations of the agricultural areas, and forested areas as well.

S&S *The idea of NASA's A-Train, with a persistent string of observations with different sensors – is that something that we're likely to see more of?*

RYAN The interplay between and among the satellites is important. Even though we have these satellites collecting data in different frequencies over the same part of the Earth, we still need *in-situ* monitoring for verification of what is being observed from space. We need to tie in the ground observations with what the satellites are sensing, and this gets us back to GEO. We're interested in integrating Earth observations, whether they are collected from a satellite, from an airplane, from a train, a ship or from a person on the ground. We are interested in bringing whatever assets there are together to answer society's problems.

S&S *Part of the challenge is in the catalog of all the observation platforms, identifying gaps, but also collaborating to fill those gaps.*

RYAN In this regard, during the first part of GEO, 2004-2009, we looked at the GEO mission as a massive cataloging effort. Then, about two years ago, we changed strategies. We transitioned to a brokering approach whereby interoperability agreements were established with institutions that have datasets and/or databases, rather than us seeking out individual datasets.

An example of this approach is illustrated with our agreement with the World Meteorological Organization (WMO). WMO members have generally registered their data in the WMO Information System (WIS). So we worked on an interoperability arrangement between GEOSS and the WIS resulting in data from one system being discovered by the other system. We are now hearing, particularly from some members in the developing world, that they are getting access to information that they didn't know existed. WMO members are getting biodiversity and ecosystem information that wouldn't normally be delivered through the WIS that focuses on weather, climate and water, and GEO members are gaining increased visibility to information in the WIS. It's a win-win story, and we'd like to have interoperability brokering agreements with any institution that wants its environmental information broadly viewed and accessible throughout the world.

S&S *Does that tie into your outreach into the private sector?*

RYAN Private companies generally still sell their data, though in some instances they share it more broadly in humanitarian and disaster arenas. We aren't advocating that every private company has to subscribe to our data sharing practices, but if they're a value-added provider or have additional information and/or services, we'd like to create a marketplace on our website for increased visibility and access to their products and services.

We want to show data that can be obtained for free from different organizations, largely government or scientific organizations. But there may be additional data that is not in the public domain that pertains to your area of interest, and we would like to facilitate that link as well.

S&S *Are there other ways that you're working on engaging the private sector?*

RYAN In November our members approved a broader stakeholder engagement strategy that would include the private sector, as well as the entire value chain: the providers of data, the value-added providers (those who build and deliver services and information products), and even the downstream representatives of our nine societal benefit areas.

For instance, in agriculture it could include John Deere or Cargill; in biodiversity it might be Conservation International. There are downstream private sector providers in biodiversity, agriculture, climate, disasters, ecosystems, energy, weather, and water. In a GEO context, the private sector would also include the development banks, foundations and nonprofit organizations.

It's an ecosystem, and if we really want to bring geospatial information, whether it's imagery or data, into this century, we've got to recognize that everybody has a role to play and those roles, while sometimes competing, can also be complementary.

S&S *Is security part of the language at GEO, relating to global change and perhaps food security?*

RYAN We have an ongoing effort called GEOGLAM (GEO's Global Agricultural Monitoring initiative).

About two years ago, we changed strategies. We transitioned to a brokering approach whereby interoperability agreements were established with institutions that have datasets and/or databases, rather than us seeking out individual datasets.

The goal is to use the global environmental monitoring assets to create a more food-secure world. In order to do that, one must reduce the volatility of food prices, and the ranges and fluctuations that we currently experience.

Production forecasts should improve from the beginning to the end of the growing season. If we are able to bring more stability to the production forecasts, we should see less volatility in prices. When production forecasts are high, prices are low; when production forecasts are low, prices are high. If we can flatten out the curves, advances in creating a more food-secure world can follow.

Many of the 25 countries that produce 80% of the world's crops have global forecasting capabilities. GEO is advocating that information from these countries be shared more broadly and openly, and that algorithms be harmonized so that forecasts are improved around the world. Global transparency will help create more stability and a more food-secure world.

A related aspect of the security issue is that governments do not want another government having easy access to what is happening over their domain with the fear that this information will be used against them. While this concern is recognized, most of the information that GEO is interested in transcends national boundaries. Atmospheric, oceanic and many terrestrial processes do not respect national boundaries, and actions in one part of the world often have wide-spread consequences. The benefits of broader data sharing almost always outweigh the risks associated with not sharing data. ▲

Alarmist or Realist?

THE ART AND URGENCY OF CREATING WORRY



Prof. Hans-Peter Plag, PhD

Climate Change and
Sea Level Rise Initiative

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[www.odu.edu/research/
initiatives/ccslri](http://www.odu.edu/research/initiatives/ccslri)

WHEN A FEW PEOPLE DIE because of a new variety of bird or swine flu emerging somewhere on the globe, the global community reacts with immediate alert and takes measures to avoid certain plausible trajectories. We are worried because we have experienced the severe impacts of global flu pandemics and still remember the extreme measures that were needed to cope and eventually contain the pandemics in 1918, 1957, and 1968. The Spanish flu in 1918-1920 killed about 50 million globally, almost as many as the 2nd World War.

Individually, we all have experiences that connect us emotionally to being affected by a flu; we know that everyone, rich and poor, white and black alike, can be affected and potentially killed by a flu. We are worried, and we appreciate that measures are taken to avoid a pandemic.

Behavioral research tells us that the 'rational actor' model does not describe human decision making satisfactorily, and the field of economics is revolutionized by these findings.¹ Neuroscience shows that the human brain is a unified, highly evolved system with complementary, rather than conflicting, components,² and as a consequence, our decisions and choices are not based on rational considerations alone but are integrated into a context of emotions, fear, hormones, and reward agents. That to which we can't relate has little impact on our decisions.

In particular, risk management is largely driven by worry.³ When we fail to be alarmed about a risk or a hazard, we seldom take precautions. Our recent personal experience strongly influences the evaluation of a risky option. The prospect of a global influenza pandemic has the preconditions required to worry us: it happens frequently enough to be present in our personal experience, and we perceive the risk as real and high. We are ready to accept what needs to be done to avoid the pandemic.

Climate change and sea level rise do not have the preconditions to worry us. Our experience is based on many centuries of relatively small

climate change and almost no sea level change. Personal experience with serious consequences of global warming is rare and mostly restricted to the poor regions in the world. Moreover, climate change is expected to affect the poor more than the rich – the developing world more than the developed world. Adaptive capabilities often depend on economic means, and the developed world is believed to have more options to adapt to new climate and sea level regimes.⁴

Worrying experience about increased sea level rise is also limited to some of the mega deltas in the developing world and a few low-lying urban coasts in the developed world. The worries are just starting to spread beyond these areas, partly because of recent experience with hurricanes like Katrina and Sandy.

Behavioral research also shows that low-probability events generate less concern than their probability warrants.³ For example, we are not too concerned about a major volcano eruption comparable to the largest ones that took place during the last 2,000 years. Today, such events would have unparalleled global consequences.

An extreme climate change and a large sea level rise during the next few decades have a low probability but they cannot be ruled out scientifically. But most of us don't seem to be worried to the extent the probability of these events deserves. The range of plausible trajectories of the planet for the next 50-100 years includes some trajectories that should be frightening.

In terms of possible temperature changes, the upper range included in the diagrams produced by the Intergovernmental Panel on Climate Change (IPCC) is already frightening enough.⁵ Some scientists consider temperature increases above the range considered by the IPCC as plausible.⁶

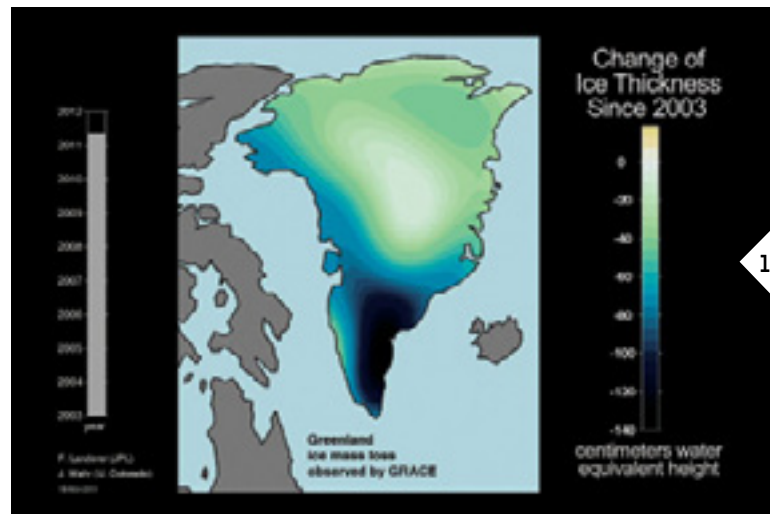
The upper range of sea level rise due to ocean warming and limited cryospheric contributions as anticipated in the last IPCC assessment⁷ would be disastrous. IPCC did not consider possible contributions from the large ice sheets, which are difficult to quantify since we don't fully understand the response of these huge ice masses to a changing climate and we have no models to predict the changes.⁸ The rapid melting of even a small fraction of these ice sheets would result in very high sea level trajectories⁹ that should virtually scare the hell out of us.

Plausible trajectories for the acidification of the oceans include trajectories that would change the marine ecosystems fundamentally with a severe impact on food security. Likewise, the plausible ranges of possible 21st century futures in terms of desertification, increases in hydrometeorological extremes, and loss of biodiversity all include trajectories that would challenge our civilization to the core. Combining some of the extreme trajectories would provide a basis for many shocking Hollywood movies.

Climate change and sea level rise have the plausible potential to kill as many people as a global flu pandemic and, in addition to that, they also could change living conditions including food, water and energy security permanently. However, scientists who point out that we have no scientific basis to rule out these extreme trajectories are in danger of being discredited as alarmists. This may explain why many of the scientists who publish papers, which show the plausibility of these alarming trajectories, seldom point out the dire consequences these futures would imply if they really happen.

Based on the recent amazing results of neuroscience and behavioral research, we can actually understand why we are not yet worried too much about climate change. But we should be. As a civilization, we need to find ways to achieve a realistic level of worry so that we can make the necessary choices to avoid these extremes, if possible.

Rationally, we know that the impact of a large asteroid would seriously threaten our civilization and kill a large fraction of the global population. However,



this low-probability event is not worrying the average individual. A few scientists, who understood the extent of the threat, convinced NASA to implement an Asteroid Watch. I am sure, if we would discover a large enough object approaching Earth we all would be very worried. The hope behind this Asteroid Watch is that we can discover an asteroid approaching Earth in time to do something about it to avoid the impact. (*Editor's note: See story on asteroid threat and policy on page 34.*)

How can we learn the art of creating worry about climate change? We certainly need more scientists who are not afraid to be called alarmists by those whose cultural, political, and emotional context blocks them from being worried by a reality that is already today causing suffering and loss and has the potential to become devastating on a global scale. We need outspoken experts who understand the meaning of probability and can fathom the threat that low-probability extreme climate change and sea level rise pose to our civilization. We need these experts to work with those who can connect to the emotions of the people: film makers, book authors, artists...and those who make a business out of being worried: the insurers and re-insurers.

Equally important, we need a much greater effort to describe the global and climate change trajectory our planet is taking so that we know as soon as possible whether we are in for one of the more extreme ones. As I pointed out in my last column, the fact that we are in the Anthropocene can be visualized with humans having moved from the backseats of the bus into the driver seat. The driver needs to have a clear view of the road in front and an understanding of the trajectory of the bus.

▲ FIGURE 1. The GRACE satellite. A key parameter for sea level rise is the relocation of water mass between the ice sheets and the oceans. The Gravity Recovery and Climate Change Experiment (GRACE) satellite, which measures tiny changes in the gravity field by monitoring the distance between two satellites, turned out to be the best tool to measure the global water cycle. This image shows increased melting of the Greenland ice sheets. An early warning system for sea level rise would have to include at least one of these satellite tandems to alert us when a rapid melting of the ice sheets endangers our urban coasts. Courtesy of NASA/JPL-Caltech/University of Texas Center for Space Research.

Already the Agenda 21, which was a result of the World Summit in Rio in 1992, emphasized the need for coordinated Earth observations and for the creation of knowledge that would support decisions for sustainable development. The World Summit on Sustainable Development in Johannesburg in 2002 reconfirmed the need for coordinated Earth observations, and this led to the establishment of the Group on Earth Observations (GEO) in 2005, basically with the task to clear the front windows and allow the drivers to see the road ahead. (*Editor's note: An interview with Barbara Ryan, Director of the GEO Secretariat appears on page 14.*) The tool for that is the Global Earth Observation System of Systems (GEOSS). The vision for GEOSS, which is a future where decisions can be informed by Earth observations, is no longer a nice-to-achieve vision; it is a necessity for the survival of our civilization.

But are we making the necessary progress? While there is some progress, for example, in areas such as a wildfire and drought services, the delivery of information to the bus drivers is still an unsolved problem. It may be the intergovernmental nature of GEO that is causing the slow progress, or the voluntary character of the organization. Cross-coordination between participants and topics is limited, greatly reducing the societal benefit of the data collected and information created, at this time.

A thorough analysis of what needs to be observed and what is missing has not been conducted, and much is addressed in a bottom-up manner leaving crucial parameters unobserved. As a consequence, we do not have the early warning systems, the "smoke detectors," that could warn us if a rapid climate shift or a rapid sea level rise is emerging. We are approaching a new Ministerial Summit on Earth Observations (the sixth since 2003), which will take place in January 2014. A small hope is that this Summit would finally respond to the urgency and take major steps to clear the front windows of the bus.

There is a chance that comprehensive Earth observations would rapidly show that we are likely to be in for the more extreme climate change and sea level rise trajectories. I am not sure whether we then would still be able to do something to mitigate or adapt, but it seems like the only way to create a global worry about climate change is by a concerted effort of realists in natural and social science, art, business, and governance. ^Λσ

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Wildfire

Sensing the Forest for Fuel, Fire & Recovery

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



5

Every year, several hundred million hectares of forest, grasslands, and other types of vegetation burn throughout the world, and this amount is set to increase due to global change, increase in drought and extreme weather. Wildfires pose a challenge for ecosystem management because they can be both harmful, threatening human life, property, economic activity; and beneficial, by regulating plant succession and fuel accumulation, affecting populations of insects and diseases, influencing nutrient cycles, etc.

Fires produce electromagnetic effects that can be detected with the use of remote sensing techniques. Remote sensing as applied for fire prevention and management involves three sets of variables:

- ▾ the phases of a fire (pre-fire conditions, active fire, post-fire burn area);
- ▾ the sensors (optical, thermal infrared, lidar, radar, and microwave—which can be satellite-based, airborne, or ground-based);
- ▾ and the key variables to be estimated and mapped (vegetation type, topography, ground fuel, and weather, especially wind speed and direction).

Before a fire, remote sensing helps with risk analysis, mitigation, and prevention planning; once

a fire starts, it helps to detect it and to respond and manage it; after a fire, it helps to map burnt areas. Each sensor has its strengths and weaknesses. The best solution is often a combination of two or more sensors and of space-based or airborne remote sensing with ground-based surveys.

Editor's note:

The front cover of this issue shows an image of an area of Colorado that is currently burning, in June 2013. More information is on page 6. This article was previously published in our partner publication *Sensors & Systems*.

KEY VARIABLES

“Fuel, topography, and weather are the three critical components to understanding how fires behave,” says David Buckley, Vice President for GIS Solutions at DTSGIS, which develops software solutions to support fire risk analysis and fire fighting. “There are detailed data for each of those and they are all combined to generate an output that will identify different conditions of threat, or probability of a fire occurring, and risk, which is the possibility of loss or harm.” See examples in *Figures 1-2*.

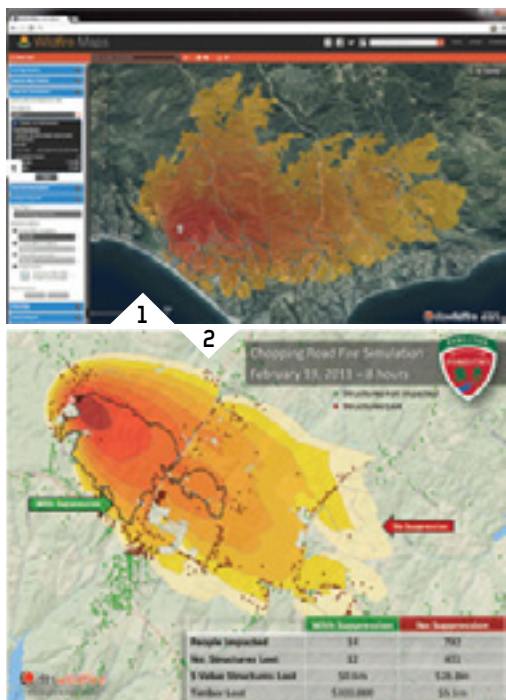
PREVENTING FIRES

“Remote sensing instruments can provide information on drought conditions, water content, fuel properties, and the state of the vegetation,” explains Tom Kampe, NEON’s Assistant Director for Remote Sensing. “Many of these systems also provide information on local weather.” Fuel type can be mapped, like classical vegetation, from optical or radar images. Whether wildfires will ignite, and how they will spread, depends also on fuel moisture. NEON is the

▲ FIGURE 5. Scientist Bryan Karpowicz monitors AOP instrumentation on a laptop during a test flight. Photo by Keith Krause, NEON.

▼ **FIGURE 1.** DTSGIS provides a suite of tools shown on this Wildfire map that includes incident management, wildfire analysis, and public-facing tools to explore incidents.

▼ **FIGURE 2.** Simulation of the Chopping Road fire, in Virginia, on February 19, 2011, courtesy of DTSGIS.



National Science Foundation-sponsored National Ecological Observatory Network that incorporates both ground-based and aerial observation, with a view toward a 30-year consistent record to understand global change.

Different types of sensors can be used to estimate fuel moisture, says Brigitte Leblon, professor of remote sensing at the University of New Brunswick, Canada. Optical sensors deployed by NOAA (National Oceanic and Atmospheric Administration), such as the AVHRR (Advanced Very High Resolution Radiometer), or by the LANDSAT, MODIS (Moderate Resolution Imaging Spectroradiometer), or SPOT missions, she

explains, enable the production of NDVI (Normalized Difference Vegetation Index) images that show how green the vegetation is; the less green it is, the more it is likely to burn. “However, greenness changes could also be due to insect infestation, fungi, or something else, so, it is not a very good indicator of fuel moisture.”

“NOAA’s AVHRR and LANDSAT also have thermal infrared bands that allow

measuring temperature increases that are produced when the surfaces are getting dryer. However, the image acquisition is limited to clear sky conditions. Radar sensors can be used to estimate fuel moisture because radar responses relate directly to the dielectric properties of the area and thus to its moisture.”

The U.S. federal government’s multi-agency LANDFIRE project (www.landfire.gov) provides data on pre-fire conditions, typically at the 30-meter level. All of these variables are used as inputs into fire danger predicting systems, such as the U.S. National Fire Danger Rating System (NFDRS), which also take into account other pre-fire conditions, such as proximity to roads and populated areas. Airborne lidar can provide additional data on vegetation types around specific assets or structures, such as homes or electric utility infrastructures.

FIGHTING FIRES

For fire fighting, early detection is essential. It currently relies on human observation, fixed optical cameras, and aerial surveys, but not on satellite sensors because of their long revisit time. For detection, Leblon explains, it is best to rely on a combination of optical and thermal sensors—the former because a fire produces visible smoke and the latter to acquire the hot spot. However, smoke is detectable only some time after a fire has started and often it is conducted along the surface and emerges far from where the fire started.

Once a fire is progressing, optical or radar sensors can be used to map the burn area. “Radar is better because you can see through the smoke,” says Leblon. “At this level, the two are very complementary. The best approach is with three sensors: optical, radar, and thermal infrared. NASA planned to have a satellite with all three, but it never happened. Thermal infrared (which adds ground and canopy fire temperatures) is always coupled with optical. We can get the optical data easily, for free—for example, from MODIS, Landsat, or NOAA-AVHRR. All three also have a thermal band, so you often have the two together.” MODIS has become the standard data source for monitoring fires at regional to global scales and is used for environmental policy and decision making. See **Figure 3**.

Besides detection and mapping, incident commanders need to predict a fire’s behavior in order to decide where to allocate crews and which areas to evacuate. “For real-time fire fighting, they use many thermal sensors for capturing where the hot sparks of a fire are and where they are through the smoke. Many of the larger state and federal agencies regularly use thermal imagery during significant fire scenarios,” says Buckley.

Three other critical types of real-time data are wind speed, wind direction, and humidity, especially in narrow valleys that create their own microclimate. “Many incident management teams use mobile remote weather stations to capture more detailed weather information on what is occurring in those valleys,” says Buckley. “It’s all about how quickly you can get accurate information.”

To observe fire behavior, microwave has the advantage that it is able to penetrate clouds and smoke, points out Michael Lefsky, an assistant professor in CSU’s Department of Forest, Rangeland, and Watershed Stewardship and the principal investigator on the High Park fire, which occurred in Colorado in June 2012.

TRADE-OFFS AND SYNERGIES

Satellite imagery provides extensive regional coverage with zero disturbance of the area viewed and enables data acquisition in less accessible areas on a regular and cost-effective basis. “The advantage of optical sensors is that they are free of charge,” Leblon points out. “For example, the U.S. Geological Survey provides georeferenced Landsat images that can be used directly without doing any fancy image processing. The major problem is the cloud cover. When you have a big fire, you can have a lot of smoke and you cannot see anything. Airborne data is very costly. Lidar, for example, is airborne only and it costs \$300 per square kilometer. Radar data, even if it is from a commercial satellite, is only \$4 per square kilometer, because the satellite is already there and the big bill was paid by the country that built it.”

The tradeoffs between optical, thermal infrared, and microwave sensors have to do with the ability to detect the fires and with spatial resolution, or how fine-scale we can actually see things, explains Kampe. For example, he points out, NASA’s satellite-based MODIS has pixel size between 250 meters and one kilometer, which limits the ability to detect small fires. Because it is an infrared system, it does not transmit through clouds, which may make it impossible to estimate the extent of fires.

Like MODIS, ASTER, which was built by the Japanese and is being flown on a NASA satellite launched in 1999, operates in the short-wave infrared portion of the spectrum. However, it has a much smaller ground footprint of about 30 meters, so you can use it to detect small fires, Kampe explains. “The tradeoff there is that you don’t get global coverage in a day. It takes quite a number of days to be able to revisit the same point on Earth.”

Microwave sensors can penetrate through clouds and vegetation, enabling detection of a fire that may be occurring in a forest in the understory. However, they are expensive and have even less spatial resolution than MODIS.

Although radar is theor-

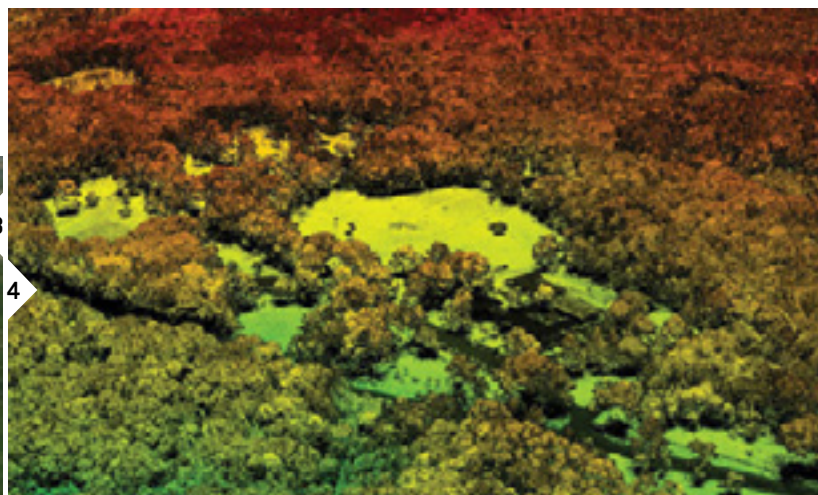
etically able to acquire imagery regardless of the weather conditions, the availability of this sensor is often limited because of the longer repeat cycle of the satellites. Additionally, while radar images have a finer spatial resolution than optical or thermal infrared images, they cover a smaller area. Thus, radar data is complementary to optical or thermal infrared data.

“Microwave or radar sensors are completely independent of weather conditions,” says Leblon. “You can even use them to acquire images at night. A microwave sensor is like a camera with a flash; an optical sensor is like a camera without a flash. If you have a camera without a flash, you are very limited as to the pictures that you can take.”

THE HIGH PARK WILDFIRE

The study of the High Park wildfire is a joint project of NEON and CSU, in collaboration with local, state, and federal agencies and land managers. It aims to provide critical data to the communities still dealing with major water quality, erosion, and ecosystem restoration issues in an area spanning more than 136 square miles. The project integrates airborne remote sensing data collected by NEON’s Airborne Observation Platform (AOP) with ground-based data from a targeted field campaign conducted by CSU researchers. It aims to help the scientific and management communities understand how pre-existing conditions influenced the behavior and severity of the fire and how the fire’s patterns will affect ecosystem recovery.

The aircraft-mounted instrumentation in the AOP includes a next-generation version of the Airborne Visible InfraRed Imaging Spectrometer (AVIRIS), a waveform lidar instrument, a high-resolution digital camera, and a dedicated GPS-IMU subsystem. “Being an airborne instrument, it has the capability to resolve features as



◀ **FIGURE 3.** MODIS provides the “big picture” view with daily fire activity monitoring. Shown here is an area of the state of Washington, U.S. Courtesy of NASA.

◀ **FIGURE 4.** A high-resolution LiDAR image from NEON airborne observation platform (AOP) test flights over Harvard Forest, MA, summer 2011. Credit: NEON.

small as a meter on the ground which enables us to detect individual trees and shrubs.” says Kampe. The combination of biochemical and structural information provided by spectroscopy and waveform LiDAR can be used to observe many features of land use and to observe and quantify pest and pathogen outbreaks, responses to disturbances like wildfire, and spatial patterns of erosion and vegetation recovery. See **Figures 4-5** on previous pages.

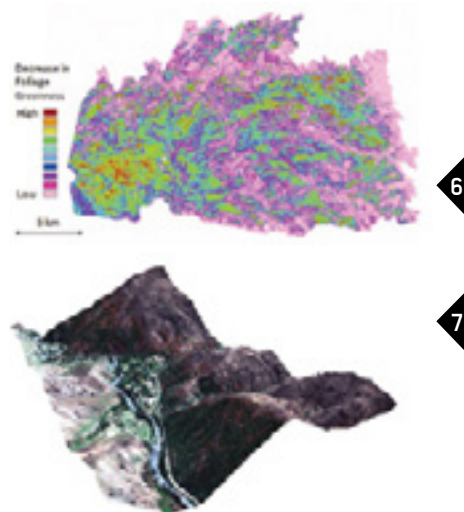
“We acquire the raw data and convert it into usable data for the scientific community,” says Kampe. “We do things like geolocation, radiometric calibration... In the High Park area, we weren’t trying to map the active fire; we were trying to map the entire burnt area and study the effects of the fire on vegetation and the ecology as a whole. In the long term, we hope to be able to look at post-fire recovery and the fire’s impact on the local

is the impact of erosion that may occur in areas that were burnt severely. Then we can also use the lidar data to map the growth in vegetation. The combination of the imaging spectrometer and the lidar makes our system and our study somewhat unique and should provide some very good information to foresters, land developers, and water resource managers.”

CSU’s team conducted the remainder of the data acquisition—the ground sampling and deriving the science from those products. See **Figures 6-8**. “The High Park fire was a target of opportunity,” says Lefsky. “It was near NEON headquarters and near CSU, where there’s a lot of bark ecology expertise, so we’re really targeting the High Park fire to look at some of these questions.”

“In the field,” says Lefsky, “we collected mostly conventional forest inventory parameters. That’s all being

► **FIGURE 6.** Fire severity expressed as decrease in foliage greenness (NDVI) between Sept. 17, 2009 and Oct. 17, 2012. Courtesy of Michael Lefsky, Center for Ecological Applications of Lidar, Department of Ecosystem Science and Sustainability, Colorado State University.



► **FIGURE 7.** Multispectral RapidEye imagery overlain over lidar digital terrain model derived from NEON lidar. Credit: Courtesy of Michael Lefsky, Center for Ecological Applications of Lidar, Department of Ecosystem Science and Sustainability, Colorado State University.

region. The lidar data has been made available to Lefsky and his team and we anticipate that the imaging spectrometer data will be made available to him shortly.”

“We are obtaining quite a lot of information and can provide many different products,” says Kampe. “We can discriminate among ash, soil, and live or dead vegetation. Looking at post-fire recovery, the imaging spectrometer gives us the ability to map the regeneration of vegetation and also to discriminate between different types of vegetation—trees vs. shrubs vs. grass—even to the point where we can determine, in some cases, what types of species are growing.”

“We get a map of the forest canopy itself and the ability to estimate such things as total biomass,” Kampe continues. “For post-fire areas, we use this to look at the state of the vegetation right after the fire. Then we subtract the vegetation and get a map of the bare ground. One of the things we look at, particularly in High Park,



► **FIGURE 8.** Burn area inside the High Park fire scar, October 2012. Photo by Jennifer Walton, NEON.

used for two purposes: to calibrate the lidar data, so that we can get estimates of how much biomass was there before the fire, and to assist us with mapping of burn severity, and presence or absence of bark beetle infestation prior to the fire. There is evidence that when burn severity is moderate, the dead trees that are left by bark beetle infestation can increase the severity and the speed at which fire burns through an area. On the other hand, when fire is really going, it doesn’t seem to make much of a difference. But that is an open research question and something that we will be examining during the study.”

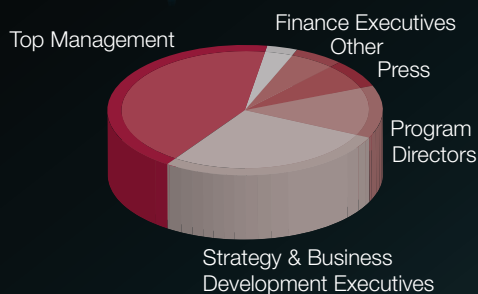
Remote sensing has become an essential tool for preventing, fighting, and managing fires. By using optical, thermal infrared, lidar, radar, and microwave sensors—often in combination—to detect its electromagnetic effects, researchers and firefighters are able to analyze the risk of fire before it starts, detect it once it starts, track its development, and map the areas burned. ▲

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David Belton, General Manager, MDA Geospatial Services
Marcello Maranesi, CEO, e-GEOS
Ryan Johnson, CEO, RapidEye
David Hodgson, Managing Director, DMCii
Miguel Bello Mora, Managing Director, DEIMOS Group
Tom Ingersoll, CEO, Skybox Imaging
Moongyu Kim, Vice President, Satellite Image Services, Satrec-I
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Diamonds

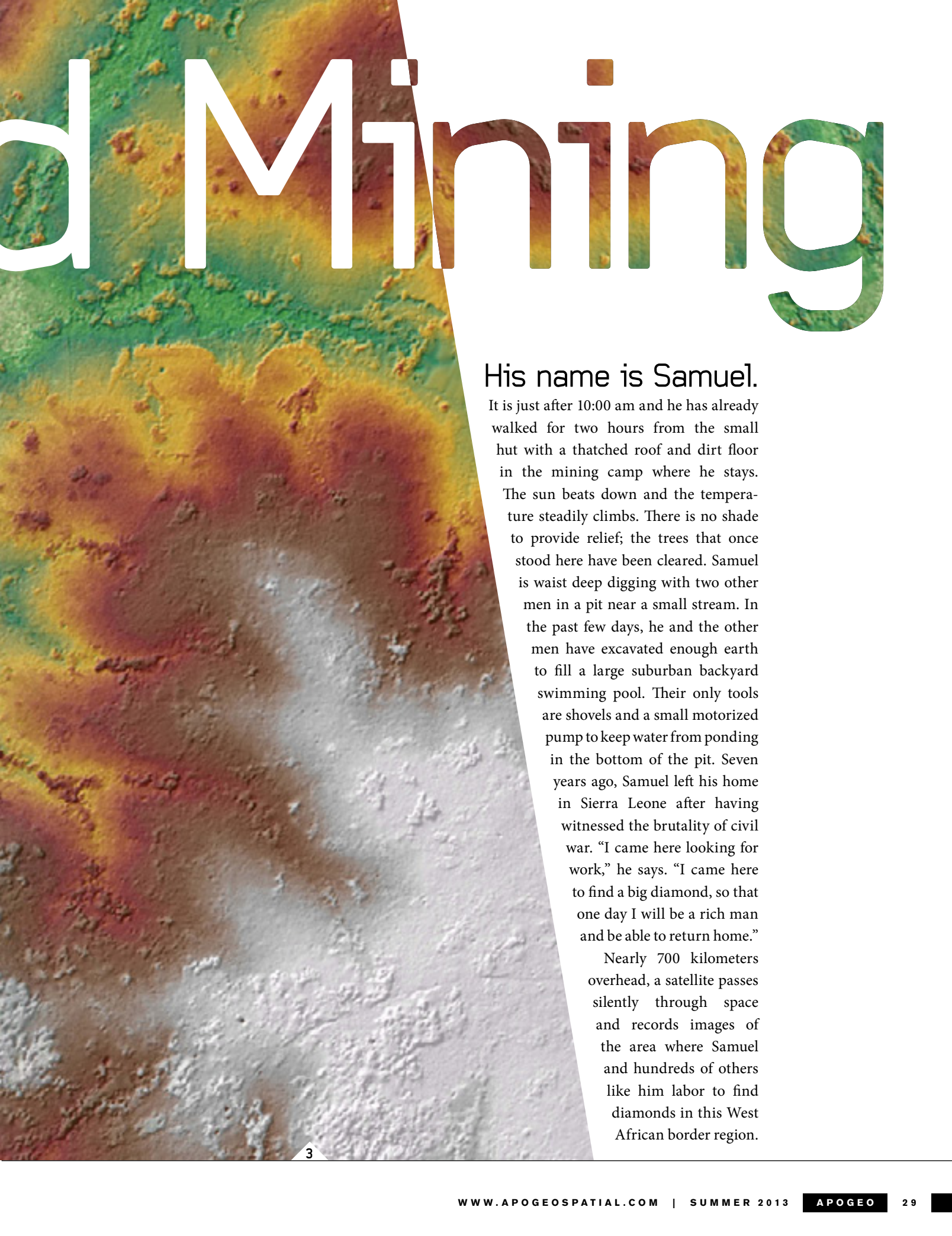
PREVENTING THE TRADE OF CONFLICT DIAMONDS AND SUPPORTING ARTISANAL MINING

BY PETER G. CHIRICO / RESEARCH GEOGRAPHER
KATHERINE C. MALPELI / GEOGRAPHIC RESEARCH ASSISTANT
UNITED STATES GEOLOGICAL SURVEY / RESTON, VA. / WWW.USGS.GOV

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Because of this association between the richness of a deposit and its geomorphology, high-resolution DEMs are a critical dataset in developing alluvial geomorphic models of the deposit zones.

FIGURE 3.
A high-resolution satellite image merged with a high-resolution DEM near Fourouna, Côte d'Ivoire. The satellite image is a 2-m resolution WorldView-2 image collected on February 13, 2013. The elevation model is a 2-m DEM derived from DigitalGlobe's IKONOS-2 stereo imagery collected on March 6, 2007.



d Mining

His name is Samuel.

It is just after 10:00 am and he has already walked for two hours from the small hut with a thatched roof and dirt floor in the mining camp where he stays. The sun beats down and the temperature steadily climbs. There is no shade to provide relief; the trees that once stood here have been cleared. Samuel is waist deep digging with two other men in a pit near a small stream. In the past few days, he and the other men have excavated enough earth to fill a large suburban backyard swimming pool. Their only tools are shovels and a small motorized pump to keep water from ponding in the bottom of the pit. Seven years ago, Samuel left his home in Sierra Leone after having witnessed the brutality of civil war. “I came here looking for work,” he says. “I came here to find a big diamond, so that one day I will be a rich man and be able to return home.”

Nearly 700 kilometers overhead, a satellite passes silently through space and records images of the area where Samuel and hundreds of others like him labor to find diamonds in this West African border region.



▲ FIGURE 1. A typical artisanal mining site: Workers begin mining in an area by digging a cluster of exploration holes until the presence of a thick and potentially rich gravel layer is found in the alluvial floodplain. Miners will then dig through several meters of sandy overburden material to access the diamondiferous gravel layer deep in the floodplain. When the gravel layer is reached, miners extract the ore and carefully sort and wash it in search of diamonds. This washing and sorting activity is completed within the active pit itself, in an adjacent pit that has filled with water, or in a nearby stream. It typically takes a team of three men one to three weeks to dig a pit, extract the gravel, and sort it for diamonds. Once the process is complete, the miners begin a new pit. Rarely, if ever, do the miners fill in previously mined pits. Old pits therefore remain exposed and typically fill with water. Photography courtesy of Peter Chirico, USGS.

CONFLICT DIAMONDS

Many of Africa's diamond deposits are mined not by industrial companies, but rather by artisanal miners like Samuel, who employ rudimentary tools such as picks, shovels, and sieves to unearth the diamonds (see **Figure 1**). Unlike large companies such as DeBeers and ALROSA, which utilize extensive

geophysical and geologic prospecting methods to locate economical diamond deposits, artisanal miners operate largely through guesswork. As a result, they expend an abundance of time and effort, with no certainty of success, and leave tracts of damaged forests, soils, water systems, and wildlife in their wake.

The deposits worked by artisanal miners are typically alluvial in nature. Alluvial diamonds have eroded from volcanic kimberlite or lamproite source rock formations and have been deposited, sometimes hundreds of kilometers away, in river beds and floodplains. They are often located in remote areas, including near or inside of protected areas and other critical ecosystems, rendering them difficult to regulate and monitor.

Artisanal mining is a high-risk, high-reward occupation with unclear or informal legal rights that can render miners vulnerable to exploitation by governments or armed groups. Exploitation often occurs either because the miners are not registered with the government, they lack legally recognized rights to the land or to resources they are mining, or they sell their diamonds through informal or illegal trade networks.

The issue of "conflict resources" emerged during the late 1990s, as details of the diamond-financed rebel uprisings in Sierra Leone, Liberia, and Angola gained public and political attention. The term has since come to refer to any natural resources that are sold or traded to finance and/or sustain violent and armed conflicts.

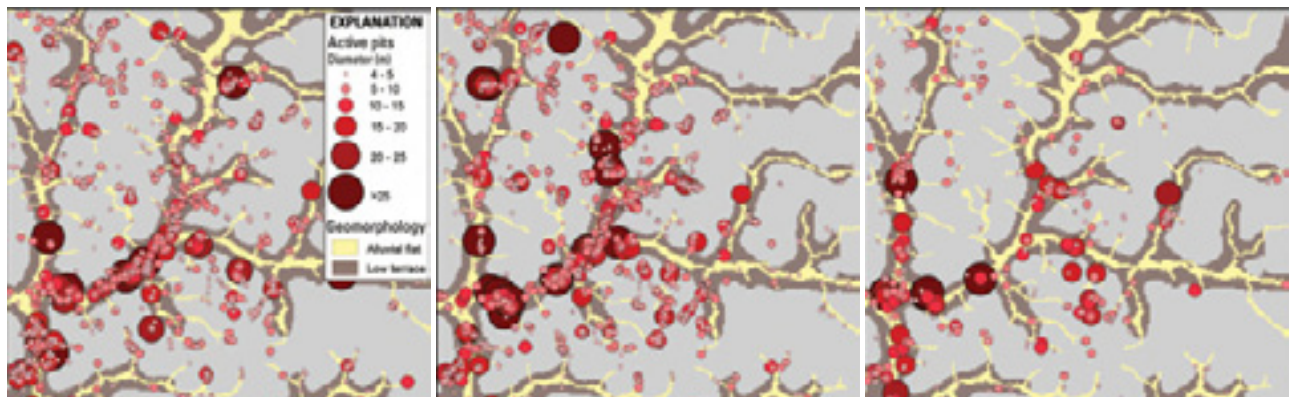
Examples include gold and diamonds, cocoa, bush meat, and timber. Of these, diamonds are perhaps the most well-known, popularized by the 2006 movie "Blood Diamond." Diamonds are a highly valuable commodity, relatively easy to access and smuggle, and difficult to trace. As such, diamonds have continued to finance conflicts, most recently in Côte d'Ivoire.

To address the concern of conflict diamonds, the Kimberley Process (KP) Certification Scheme was established in 2002 by representatives of the diamond industry, non-governmental organizations (NGOs), and governments of diamond exporting and importing countries, with the goal of ensuring that rough diamonds traded by participating countries were not used by rebel movements, or their allies, to finance armed conflicts aimed at undermining legitimate governments.

The Clean Diamond Trade Act (Public Law 108-19) officially sanctions U.S. participation in the KP, and authorizes the U.S. Department of State (DOS) to engage with other U.S. government agencies to provide technical expertise to participating countries within the KP. The DOS (including the Special Advisor for Conflict Diamonds), the U.S. Agency for International Development (USAID), and the U.S. Geological Survey (USGS) Special Geologic Studies Project currently work in close partnership to assist several West African nations in mapping, monitoring, and performing national-scale assessments of their artisanally mined diamond deposits.

Collaboration also takes place between the U.S. government and the national mining ministry and civil society organizations of the countries receiving technical support. Such multilateral partnerships provide technical training, the transparent exchange of information among governments, civil society, and the general public, and support and training for host countries in assessing and regulating their diamond resources.

While diamonds have clearly been linked with political unrest and instability, artisanal diamond mining



also has the potential to provide positive socioeconomic impacts, serving as a means of supplementary income and supporting the local economies of mining communities. However, there is a significant lack of data concerning the location and richness of the deposits, limiting knowledge of where diamonds can be mined economically. The collection and dissemination of such information would improve both the success of the individual miner and the effectiveness of the development programs that target these populations, as well as verify the value of the nation's artisanal mineral deposits. Addressing this lack of data is an important part of understanding diamonds as a conflict resource and also as a potential development tool.

THE ROLE OF SATELLITE IMAGERY

Satellite image interpretation of artisanal mine sites is an integral component of producing comprehensive assessments of alluvial diamond deposits. Repeat-pass, high-resolution commercial imagery, such as that from DigitalGlobe's (Longmont, Colo.) WorldView-1 and WorldView-2 satellites, is used to perform change detection analysis in order to assess the location, size, and distribution of mining pits and activities (see *Figure 2*). Furthermore, stereo satellite image pairs, including those collected by DigitalGlobe's IKONOS and GeoEye-1 satellites, are used to generate high-resolution digital elevation models (DEMs) to distinguish large mining pits and subtle landform features, such as paleochannels, alluvial flats, and terraces, which can indicate potential diamond deposition and accumulation (see *Figure 3* on page 28). The identification of heavily-mined areas and new mining zones through these methods helps direct fieldwork aimed at assessing the deposits and the communities who mine them, and enables researchers to be more efficient in these challenging and often difficult-to-access regions.

During the satellite image interpretation process,

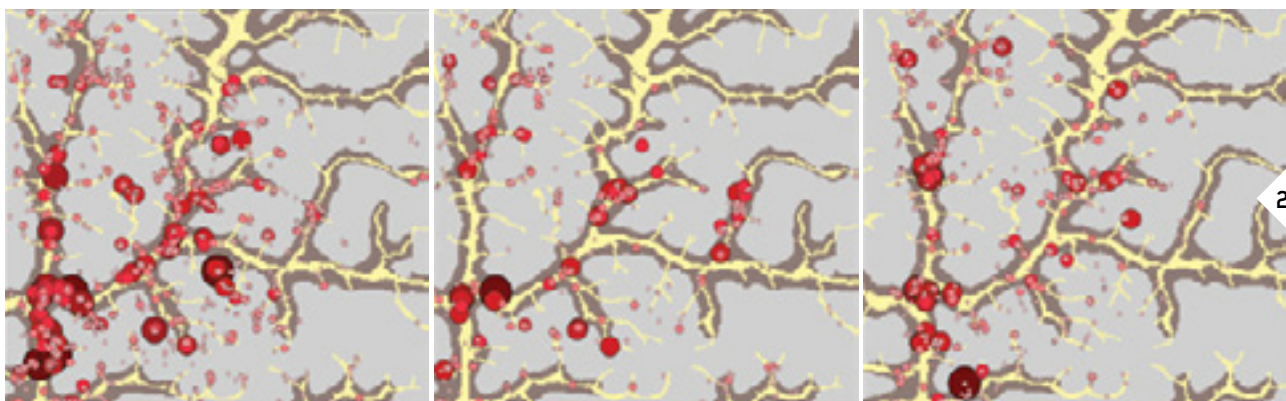
individual mine pits are identified and assigned an estimated activity level and type of mining activity. Interpreters identify pits as being active or inactive, exploration or extraction pits, and measure their dimensions. Active pits typically exhibit a rim of brightly reflective excavated sediment material surrounding the edge of the pit and nearby spoil material piles (see *Figure 4*). In addition, the bottoms of such pits contain little or no water as miners frequently use pumps to drain pits during the excavation process. The presence of water is a key indicator of inactive mining, as is the presence of vegetation around the outer rim of the pit.

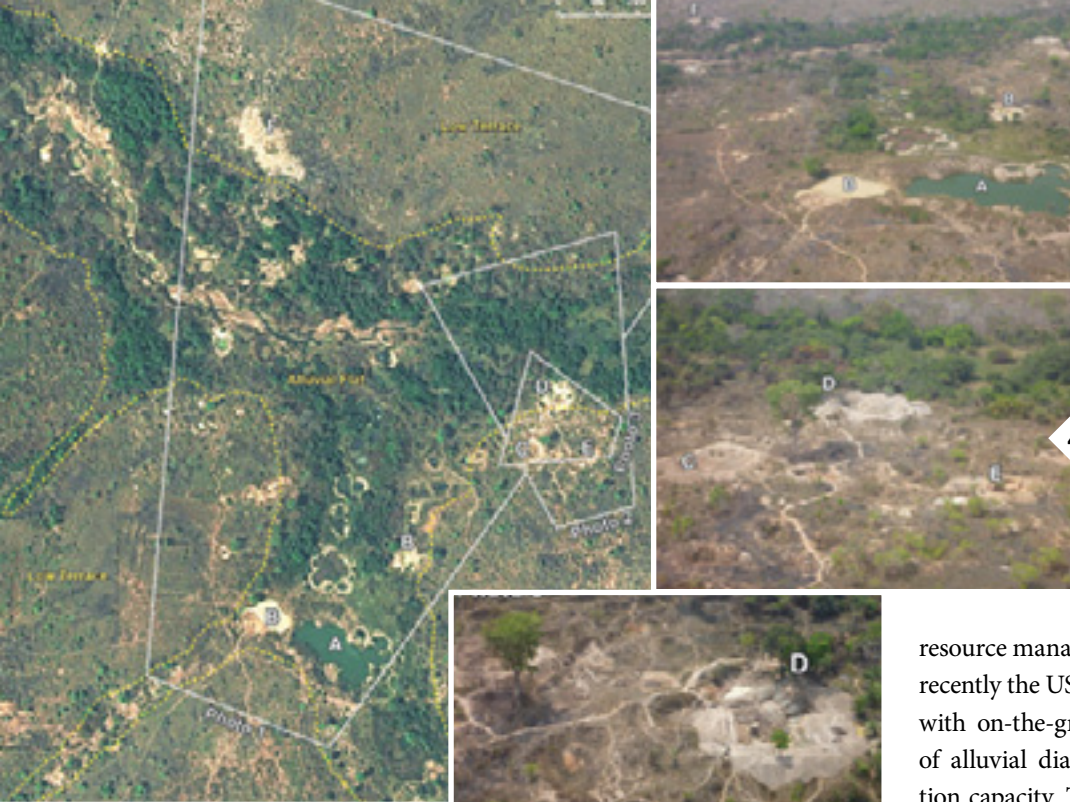
Active mining pits may range in size from 1-30+ m in diameter, and are frequently several meters deep. Exploration pits are usually 1-3 m in diameter and are dug as test pits to determine if diamonds are present at a particular location. If diamonds are not found, the miner will typically begin a new exploration pit nearby. If diamonds are found, the exploration pit will be expanded in order to improve the chances of discovering more diamonds. Pits located in the alluvial flat, or floodplain, tend to be deeper and have higher diamond potential, whereas pits located on terraces just above the floodplains are shallower and more easily accessed, but tend to contain lower grade deposits. Because of this association between the richness of a deposit and its geomorphology, high-resolution DEMs are a critical dataset in developing alluvial geomorphic models of the deposit zones.

BEYOND CONFLICT DIAMONDS

The ability to obtain accurate and detailed information on artisanal mining activities by satellite is invaluable for researchers and policy makers, and greatly assists in the assessment of deposits that are difficult to access, as they are remote and have associated safety concerns. While this method has been implemented in support of the KP's mission to end the trade of conflict diamonds, researchers are now employing similar techniques to

◀ **FIGURE 2.** A time-series analysis showing active artisanal mining extraction pits at a site in West Africa, created from a series of high-resolution satellite images documenting mining activities from 2006-2012 (2011 omitted because of differing image extent). Changes in the location and size of the pits are visible, and provide insight into the activity level within the study area from year to year. Graduated symbols correspond to the size of pits. Images courtesy of USGS.





▲ **FIGURE 4.** A comparison of oblique aerial photography on the right, and a Worldview-2 satellite image on the left. The Worldview-2 image, collected on Feb. 3, 2012, shows the intense mining activities of artisanal miners in a floodplain in West Africa. Oblique photography collected at the same site in June 2012 shows a detailed view of the active and inactive mining pits. [A] Large inactive mining pit which has now filled with water; [B] Two previously mined pits that have filled with water and sediment, indicating that they were recently used for washing and sorting gravel; [C] A recently abandoned pit with eroded headwalls that has not yet filled with water, indicating recent but completed activity; [D, E] Large active mining pits with the headwalls visible where miners are in the process of excavating. The particularly bright reflectance of the recently-removed spoil materials surrounding the pits in the satellite image is further evidence of the pits' activity; [F] A cluster of small exploration pits in the low terrace geomorphic zone. Satellite image courtesy of Digital-Globe, Inc. Aerial photographs courtesy of Simon Gilbert, United Nations.

assess and monitor other conflict minerals, such as the artisanal mining of tantalum, tungsten, tin, and gold in the eastern Democratic Republic of the Congo, a region destabilized by decades of conflict.

More accurate and detailed information on artisanal mining also assists development programs aimed at formalizing and legalizing the sector, assisting in micro-financing investment, and implementing sustainable development initiatives that target artisanal mining communities. For example, detailed satellite imagery of existing and potential mine sites help to inform the most appropriate type and location of development intervention, from clarifying land tenure in diamond-rich areas to promoting complementary livelihoods in areas that may be less diamondiferous. In the Central African Republic, basic geologic data collected through satellite image analysis has assisted USAID's Property Rights and Artisanal Diamond Development (PRADD) project's mission to secure the land and resource rights of artisanal miners and to introduce successful environmental rehabilitation programs, such as aquaculture and vegetable

farming, in exhausted mine sites.

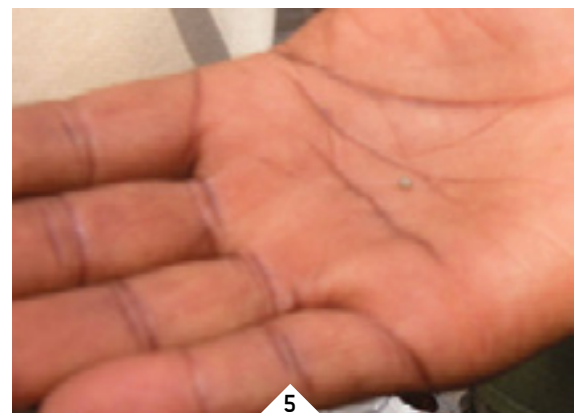
The instrumental role of satellite imagery in monitoring conflict diamonds through the acquisition of critical information related to the deposits is clear. As commercial sensors continue to be developed with improved spatial and temporal resolutions, the potential impact of remote sensing technologies to assist with curtailing the flow of conflict minerals will only increase, by providing essential and timely information to

resource managers and policy makers. As an example, recently the USGS integrated satellite imagery analysis with on-the-ground field visits to develop estimates of alluvial diamond resource potential and production capacity. The results of these assessments can be used to locate data anomalies in production statistics and support the KP in identifying potential cases of unregulated or illegal exports. Such activities, in addition to development projects such as USAID's PRADD program, are examples of the multidimensional uses of satellite imagery in the study of natural resources and the complex issues that surround them.

CONCLUSION

After a week of digging, Samuel has found one small diamond, not much larger than a grain of sand (see **Figure 5**). He will sell it to a diamond buyer in a nearby village for no more than \$20, just enough money to buy food and supplies to sustain him for a week or two. More important, it is just enough to keep his hope alive that one day he will discover a big diamond, become a rich man, and return home. ▲♣

▼ **FIGURE 5.** A small diamond found by an artisanal miner. Photograph courtesy of Mark Van Bockstael, the Antwerp World Diamond Centre.



CAPTURING THE INDUSTRY DYNAMICS INNOVATION & OUTREACH



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Home Planet Earth in the Cross-Hairs

Getting to Know NEOs

BY LEONARD DAVID / CONTRIBUTOR / BOULDER, COLO.

There is an ongoing, global hunt for asteroids and other hazardous natural objects that may have cross-hairs on our home planet. These near-Earth objects (NEOs) are asteroids or comets with an array of sizes and shapes that orbit the Sun and whose orbits come close to that of Earth. There are over 600,000 asteroids known in our solar system, and almost 10,000 of them are NEOs.

NEOs have—and surely will in the future—thumped our world and shaken up our life-sustaining ecosystem. Indeed, over the eons, it has been a celestial slugfest. Comets and asteroids have struck the Earth since its formation 4.5 billion year ago. On one hand, there is no need to toss and turn in bed worrying about a massive space rock mussing up our world. However, while the odds of a nasty impact here on Earth in the near future are small, they are not zero...and the consequence of a hefty NEO colliding with the planet would be extreme.

But one recent incident quite literally punctuated that prospect. A large fireball—also termed a “superbolide”—detonated at 9:22 a.m. (local time) on February 15, 2013 over the city of Chelyabinsk in Russia and is considered by many experts as a 21st century cosmic wake-up call.

That previously undetected object, thought to be 55-65 feet (17-20 meters) in diameter struck the atmosphere moving at about 40,000 miles per hour, exploding nearly 15 miles (24 kilometers) above Chelyabinsk with 20-30 times the energy of the Hiroshima atomic bomb. The shock wave it



produced at high altitude took nearly 90 seconds to reach the landscape, destroying many windows in that city and in surrounding towns, with numbers of people wounded by flying fragments of broken glass. A part of the roof and a wall of a zinc plant and a stadium in Chelyabinsk were also damaged. See *Figures 1-2*.

The fireball's shock wave caused widespread damage

▲ FIGURE 1.

Trace of an alien visitor: An object entered the atmosphere over the Urals early in the morning of February 15, 2013. The fireball exploded above the city of Chelyabinsk, resulting in damage to buildings and injuries to hundreds of people. This photo was taken by Alex Alishevskikh about a minute after noticing the blast. Credit: Alex Alishevskikh, courtesy European Space Agency.

◀ FIGURE 2.

An image from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) instrument's High Resolution Visible (HRV) channel aboard Eumetsat's Meteosat-10 geostationary satellite. The vapor trail visible was left by an asteroid that struck Earth near Chelyabinsk, Russia on February 15, 2013. See Figure 1. Credit: Eumetsat.

and injuries making it the largest known natural object to have entered the atmosphere since the 1908 Tunguska event. That history-making saga involved a rocky impactor that detonated over remote Siberia, toppling about 500,000 acres of forest.

Getting to know NEOs has a very real, practical side: There's need to find them before they find us. We live in a cosmic shooting gallery, so ways to defend ourselves from NEOs need careful study. If there is adequate warning time, we have the means to guard the Earth from impacts—a luxury that apparently the dinosaurs were not afforded.

By making use of ground and space-based technology, humankind does have the ability to anticipate a large-scale impact. Preventing such an occurrence is another matter. To protect life from such a vicious event is an environmental challenge, one that calls upon integrating technology, space policy, and international involvement to launch a global response.

KNOW THE ENEMY

Protecting our planet from impacts by NEOs means getting to know the enemy, some of which are very large. See **Figure 3** on page 36.

The seriousness of the issue brought together nearly 300 authorities from around the world to attend the International Academy of Astronautics' Planetary Defense Conference, held April 15-19 of this year in Flagstaff, Arizona—a meeting co-sponsored by Secure World Foundation (SWF), NASA, the European Space Agency, the Japan Aerospace Exploration Agency, the Romanian Space Agency, the United Kingdom Space Agency, and ROSCOSMOS, the Russian Space Agency. See **Figure 4** on page 37.

The good news here is that the involvement of these agencies is crucial since planetary defense is an international concern. Should an object on an Earth impact trajectory be discovered, it is possible, and in fact likely, that several space-faring nations would be involved in a deflection/disruption campaign.

Papers given covered such topics as discovering NEOs, characterization of the objects, mitigation techniques and missions, as well as impact effects, consequence management and education.

What might be done to prevent an impact if a threatening object on a collision course with Earth is discovered?

Garnering the most discussion at the meeting were overviews of the latest research on deflection and disruption techniques and on missions and techniques

The Critical Role of Citizen Sensors

The Chelyabinsk fireball event over Russia highlighted the value of “citizen sensors,” noted a blog entry in the Commons Lab, a group within the Science and Technology Innovation Program of the Woodrow Wilson International Center for Scholars in Washington, D.C. The Commons Lab draws attention to the use of everyday sensors, readily available to the public, to spot problems, gather and interpret data, and act on the results.

While official and standardized sources were providing valuable information on the Russian skyfall, so too have decentralized citizen sensors. The number of omnipresent dashboard-mounted and hand-held cameras yielded remarkable footage at the same time traditional news outlets picked up the story.

“The ubiquity of these affordable recording devices allowed people in and around Chelyabinsk to document a rare and scientifically significant situation...and some of the best footage showed up on news broadcasts around the globe,” the Commons Lab blog noted. Using all the video, scientists were able to determine that the meteor flew in at a shallow angle of 20 degrees above the horizontal, described as a “grazing impact” through the atmosphere.

The Russian fireball depicts “the new status quo,” the Commons Lab reported. Although citizens might not be replacing traditional media, they are certainly supporting it. The amateur footage from Chelyabinsk provides on-the-ground real-time perspective that previously went unrecorded.

“Rapidly evolving communications, sensing, and mapping technologies have placed the extraordinary power of mass data collection and analysis into the hands of citizens, communities, governments, and businesses,” the Commons Lab concluded.

that might deliver a deflection/disruption payload to an Earth threatening object. A diversity of ideas, concepts and techniques are on the table, be they smacking into a NEO with a high-speed projectile, laser-blasting the object, or even using nuclear detonations.

COMMUNICATIONS STRATEGY

Also presented at the unique planetary defense gathering was SWF's report on NEO risk for media and communications in support of deliberations on the matter by the United Nations. Secure World Foundation and the Association of Space Explorers hosted a 2011 workshop to explore the communications components of an International Analysis and Warning Network. That two-day workshop brought together journalists, scientists, policy makers, and experts in risk and disaster management to scope out the elements of an effective communications strategy and provide guidance for an outreach and education plan as central elements of an effective response plan to the NEO threat.

Establishing an effective international communications strategy for potentially hazardous NEOs or an impending NEO strike is a daunting task that will require effective use of mass communication tools, from television to the Internet, and other information channels and technologies. General education should include information about NEOs and their place in our solar system, the nature of the potential threat, and

specific information related to warnings of a potentially hazardous NEO.

A key organization that has focused on what to do about NEOs is the United Nations Scientific and Technical Subcommittee's Action Team on Near-Earth Objects (AT-14), under the wing of the UN Committee on the Peaceful Uses of Outer Space. AT-14 was established in 2001, keen on pushing forward an international response to the NEO impact threat.

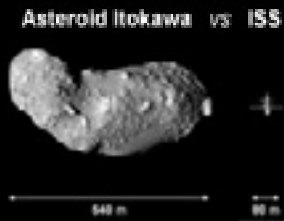
NEXT STEPS

The 56th session of the Committee was held in Vienna from June 12-21, 2013 and flagged the tireless work of the AT-14—not only in appraising the current field of knowledge regarding NEOs, but also underscoring recommendations of AT-14 for an international response to the near-Earth object impact threat. Specifically, the next steps include establishment of an International Asteroid Warning Network (IAWN) and a Space Mission Planning Advisory Group (SMPAG).

In short, IAWN would be open to contributions by a wide spectrum of organizations, and should be established by linking together the institutions that were already performing, to the extent possible, a variety of functions, including discovering, monitoring and



▼ FIGURE 3. Asteroids come in all sizes, as depicted in this montage of the Itokawa asteroid using the International Space Station for scale. Credit: Pascal Lee, NASA.



Getting an Eyefull: Space-Based Viewing

There's an important new aspect to NEO research. Data gleaned by U.S. sensors aboard secretive spacecraft that spot bright bolides (fireballs) entering Earth's atmosphere will now be posted on a NASA Near-Earth Object Program Office website.

A newly crafted Memorandum of Agreement (MOA) has been inked between the space agency's Science Mission Directorate, and Headquarters Air Force Space Command, Air, Space, and Cyberspace Operations Directorate. That MOA outlines the public release

of bolide data and was signed on January 18, 2013. Data collected by spaceborne sensors on the recent Chelyabinsk event, for example, has been posted to highlight characteristics of the Russian "superbolide" explosion.

The upshot is that NASA's Near Earth Object Observation Program is receiving information on bolide events based on analysis of data collected by U.S. Government sensors. The MOA signals a renewed collaboration between the U.S. military and the scientific community.

Other groups are also eyeing

use of space sensors to prowl for worrisome NEOs.

The B612 Foundation is dedicated to opening up the frontier of space exploration and protecting humanity from asteroid impacts. The Foundation is moving forward on its plans to build and operate the first privately funded, launched, and operated interplanetary mission—an infrared space telescope to be placed in orbit around the Sun to discover, map, and track asteroids whose orbits approach Earth and threaten humanity. See *Figure 5*.

"We've been given a gift,



There's an important new aspect to NEO research. A newly crafted MOA has been inked between the space agency's Science Mission Directorate, and Headquarters Air Force Space Command, Air, Space, and Cyberspace Operations Directorate. That MOA outlines the public release of bolide data and was signed on January 18, 2013.

physically characterizing the potentially hazardous NEO population and maintaining an internationally recognized clearing house for the receipt, acknowledgment and processing of all NEO observations. Such a network would also recommend criteria and thresholds for notification of an emerging impact threat.

SMPAG should be established by Member States of the United Nations that have space agencies. The group should include representatives of spacefaring nations and other relevant entities. Its responsibilities should include laying out the framework, timeline and options for initiating and executing space mission response activities. The group should also promote opportunities for international collaboration on research and techniques for NEO deflection.

"The work of AT-14 is not yet finished," said Sergio

Camacho, Chair of the Action Team on Near-Earth Objects, with the group now geared to assist in the establishment of IAWN and SMPAG. Once founded, IAWN and SMPAG would report, on an annual basis, on the output of their work, he noted.

Concerning "the giggle factor" long associated with worrying about NEOs, "that's gone, over and done with," emphasized Ray Williamson, a senior advisor to the Secure World Foundation, a member of AT-14, and editor of this publication. He underscored the increasing awareness of the issue worldwide. "And that is worth something...in the sense that now countries are aware they need to put some expertise and resources into the equation to provide information that would ultimately protect Earth from these threatening asteroids." ☿

◀ FIGURE 4. Experts from around the globe met at a Planetary Defense Conference, held April 15-19, 2013, in Flagstaff, Arizona. The meeting included an exercise where participants simulated the decision-making process for developing deflection and civil defense responses to a hypothetical asteroid threat. Credit: Leonard David.

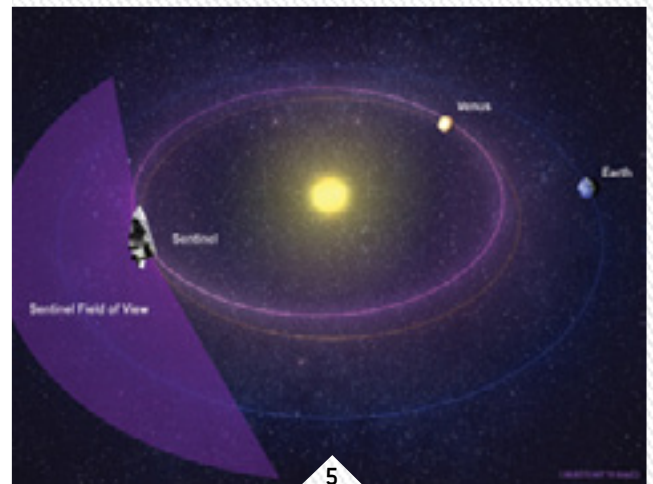
and the gift is that we have the ability now to go out there and actually do something which positively affects the future of humanity on Earth," said Ed Lu, B612 Foundation Chairman and a former astronaut.

The B612 Foundation's Sentinel Mission is intended to provide a unique opportunity for the public to take ownership in a historic space mission that will protect Earth. With decades of advance notice provided by Sentinel, there is ample time to prepare and launch a deflection campaign.

The Russian fireball detonation earlier this year was "Mother Nature at her surprising best!"

That's the view of Apollo astronaut Russell Schweickart, Chair Emeritus of the B612 Foundation of Mountain View, Calif.

Mark Boslough, a NEO expert at Sandia National Laboratories in Albuquerque, New Mexico, is a supporter for a NEO-spotting, space-based infrared telescope. "Right now our surveys are like looking one way before we cross the street," Boslough told Apogeo. "That would be OK if it were a one-way street, but as Chelyabinsk showed, asteroids are coming from both directions, the night sky and the daytime sky. To be safe, we need to survey the daytime sky and we can only do that from space."



▲ FIGURE 5. Now on the drawing boards, an infrared space telescope can be placed in orbit around the Sun to discover, map, and track asteroids whose orbits approach Earth and threaten humanity. Credit: B612 Foundation.

Measuring D

Remote Sensing for Siting Wind Turbines

BY MATTEO LUCCIO / CONTRIBUTOR

PALE BLUE DOT LLC / PORTLAND, ORE. / WWW.PALEBLUEDOTLLC.COM

Wind's contribution to energy production in the United States continues to grow. In 2011, it represented a third of all new electric generating capacity. Individual wind turbines are getting larger in power-generating capacity, hub height, and rotor diameter—largely in order to make wind turbines viable in areas with lower wind speeds. This growth is expected to continue.

Decisions about where to site commercial-scale wind turbines—typically costing \$3-4 million each installed (though their cost drops significantly with economies of scale for large wind farms)—require detailed, reliable, and long-term data about wind speed and direction. Wind speed maps and tables published by the National Renewable Energy Laboratory (NREL), the U.S. Department of Energy's primary laboratory for renewable energy and energy efficiency research and development, are a good starting point.

However, resource assessment (to identify locations with sufficient wind speeds for turbines to work efficiently) and forecasting (to know whether the long-term average wind speeds make investments in wind energy cost-effective) require much more detailed knowledge of local wind conditions. Additionally, real-time measurements of the speed of approaching wind gusts, fed into the turbines' control systems, can enable them to instantly adjust the gears so as to maximize energy production while minimizing the chance of mechanical failure.

Currently, the two preferred technologies for collecting wind data are ground-based SoDAR and LiDAR.

REQUIRED DATA

Siting decisions for wind turbines typically require a few key types of data. "Initially, we do some

meso-scale modeling for a particular region," says Dr. Jeffrey Freedman, the Lead Research Scientist at AWS Truepower, LLC, a renewable energy consulting company with a staff of approximately 75 meteorologists, engineers, and environmental specialists. "We will couple that with terrain-based models that will tell us at 50-meter to 100-meter resolution roughly what the wind speed is at 80 meters or 100 meters above the ground and that gives you a rough idea of what the wind speed field looks like."

Next, on-site measurements of wind speeds are necessary in order to estimate how they will vary over the project's lifetime. "That tells you essentially how much money your project is going to make based on the type of turbine that you are going to put out there," says Freedman. This requires at least a year's worth of continuous measurement from towers. However, because most towers are lower than the turbines' rotor planes, SoDAR or LiDAR sensors are used to study local wind shear (the change of wind speed and direction with height).

Finally, he explains, you need a description of the wind climate, which requires longer-term data. "You hope that somewhere nearby there is a long-term climate station that has a record that is 10, 15, or 20 years in length. Then you do a statistical regression between your short-term measurements on site and the longer-term climate station measurements and use that


Instant Winds

relationship to project what you think the long-term wind climate is on site.”

Daniel Ngoroi, Remote Sensing Team Lead for Woolpert, a large design, geospatial, and infrastructure management company, would combine this wind data with elevation datasets derived from the airborne LiDAR data that his company produces. He would also gather land use and land cover maps. “I want to know where my open fields are, where my forests are, where water is. I also want the zoning information, if the area is zoned, and wind turbine guidelines published by various government agencies, which are supposed to guide you in determining areas that are restricted, based on certain wildlife or vegetation. One of the issues with wind turbines over the years has been the obstruction of migratory paths for certain birds.”

Additionally, says Ngoroi, “it would be nice to have things like transportation and transmission line data that allow me to build buffers around those

transportation corridors and transmission line corridors, because wind turbines need to be located within certain distances of transmission lines, in order to be able to get the energy to wherever it needs to go. So, if you take all those pieces of data together, then you can produce maps that show suitability zones: here is the area that has this amount of wind speed, usually a sustained wind speed of 10 miles per hour and above, and then it intersects this land use category and it is close to this transmission line corridor and to this transportation corridor.” See *Figures 1-2*.



◀ FIGURE 1.
Big Horn
Wind Farm.
Photograph
by Iberdrola
Renewables,
Inc. Courtesy
of NREL.

1

LiDAR

Airborne and ground-based LiDAR sensors are usually used for measuring and imaging hard surfaces, such as terrains or buildings. For the purpose of measuring wind speed, however, they are pointed upward from the ground and the backscatter energy reflects off of aerosol particles in the air that are moving due to wind turbulence. Wind speed and direction is then derived by measuring the Doppler shift and mapping it into a model.

“Even though the air might seem clean, there are plenty of dust and dirt particles floating out there at the sizes that you need and given the wavelengths at which you are transmitting,” explains Freedman. “They are in sufficient concentration to generate a decent amount of statistics to give you the average wind speed and direction over periods of a few minutes. Typically, LiDAR will give you decent measurements, depending upon their transmission power, in the thousands of meters vertically or horizontally.” See *Figure 3*.

► **FIGURE 2.** Blue skies and calm conditions contributed to a smooth installation of a General Electric 1.5 MW wind turbine at the National Wind Technology Center. Photograph by Pat Corkery. Courtesy of NREL.

► **FIGURE 3.** Leosphere scanning LiDAR owned and operated by the Hawaiian Electric Company (HECO) at the Kahuku Wind Farm. Photo by Matthew Filippelli. Courtesy of AWS Truepower.

► **FIGURE 4.** Atmospheric Research and Technology SoDAR owned and operated by the Hawaiian Electric Company. Photo by Amra Brightbill. Courtesy of AWS Truepower.

SoDAR

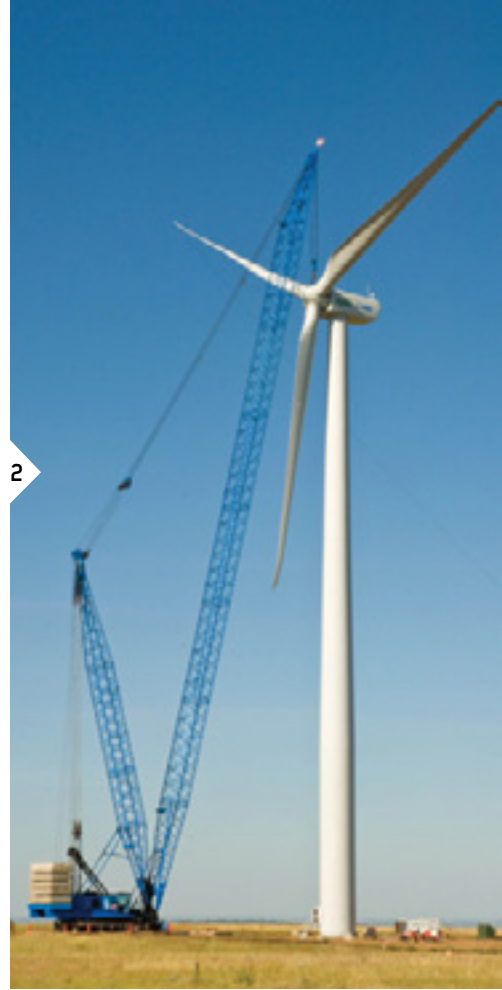
SoDAR sensors send out sound pulses that reflect off of turbulent eddies containing local gradients of temperature and wind speed, explains Andrew Clifton, a Senior Engineer at NREL. Typically, he says, “you send out one or more beams to describe an arc above the device. That way, because you are looking at the wind field from several different directions, you can back out the vector of the wind that is moving through the points. Often, you look up, then you look north, and then you look east, with an off-vertical angle of 30 degrees for both directions. There are many variations on this technology.”

In most cases, assuming that there is no acoustical interference, SoDAR will be a very good data source in terms of describing the vertical profile of the wind direction, says Freedman. Even though SoDAR sensors cost between \$50,000-100,000, they are cheaper in the long run than building towers. See *Figure 4*.

COMPETING TECHNOLOGIES

The data collected using LiDAR or SoDAR can be quite similar, says Clifton. “We normally get the wind speed and direction at multiple heights above ground, which tend to be anywhere from 10-300 meters. We’re also seeing new types of LiDAR on the market that allow us to measure out to about 15 miles and measure the wind speed in the line of sight in a small area.”

SoDAR and LiDAR are somewhat competing technologies. “Many people were familiar with SoDAR technology from meteorology; it has been used quite intensively by national meteorological services and by universities over the last 15-20 years, if not longer,” Clifton points out. “However, it tends to require attended operation and suffers a little bit with signal attenuation over height. LiDAR systems started to become commercially available about eight years ago and have since become cheaper and more widely available. So, we are now at the point where SoDAR and LiDAR have slightly different costs and benefits.”



“SoDAR is the baby brother to LiDAR, owing to its limitations, but it has its place in wind energy studies,” says Ngoroi. “It is an older technology that is now being retired and rapidly replaced by Doppler LiDAR.”

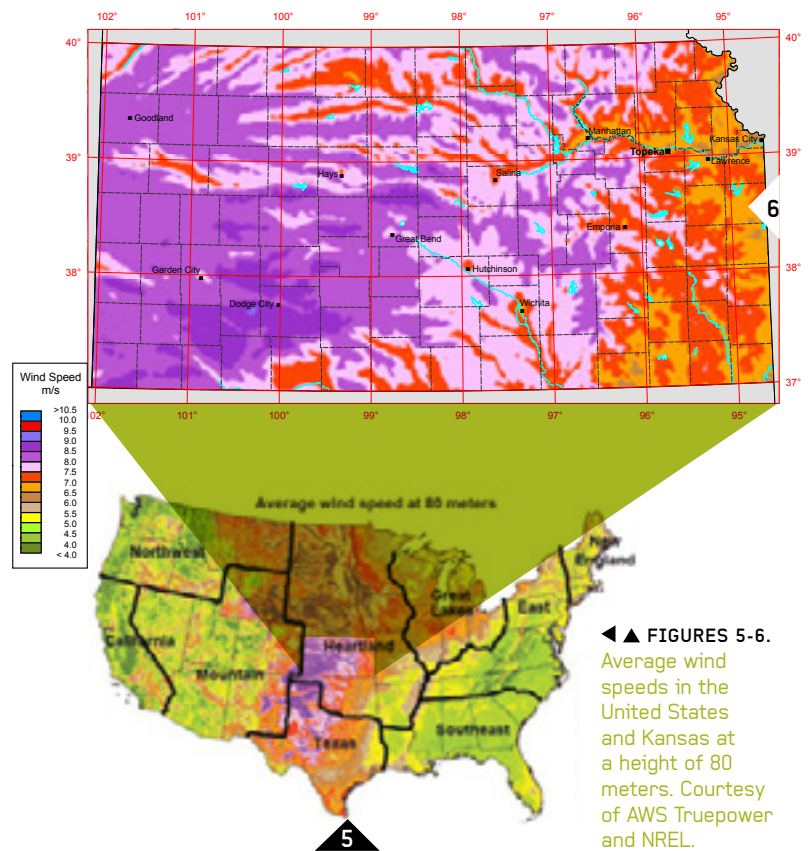
RESOURCE ASSESSMENT

To determine the suitability of an area for wind turbines, “you have to start with something,” says Ngoroi. “Usually, the place to start would be the published wind speed maps. However, they cover such wide areas, that you want to narrow that down to something that covers the average area of a wind farm.” See **Figures 5-6**.

Traditionally, for resource assessment, the industry has used towers 40-80 meters high with instruments mounted on them that provide point measurements at various levels, says Freedman. “The problem is that these point measurements are not representative of where today’s larger wind turbines are operating, because the typical hub heights are now 80 meters, 100 meters, or even 120 meters. That means that their rotor plane can extend up to 150 meters in height. There are empirically based relationships that give you the change in wind speed with height (that is, the wind shear). The problem is that we don’t know for certain how representative that estimate is.” Additionally, the number of existing towers is tiny compared to the number of potential locations for wind turbines and it is very expensive to build new ones.

That is why wind energy engineers use remote sensing instruments to measure wind speeds. “They will give you measurements that extend through the rotor plane,” says Freedman. “Typical SoDARs that we use have measurement heights of up to 200 meters. Both SoDAR and LiDAR are typically used as vertically-pointed instruments that give you a volumetric measurement, because they are giving you a sample volume at different levels, say, from 30-200 meters at 10-20-meter height increments. So, that’s giving you a more representative wind description. The industry is slowly moving in that direction. Frequently, you will find resource assessment campaigns that pair tower-based measurements with shorter-term deployment of SoDARs and LiDARs.”

The future in the industry is in remote sensing, Freedman argues, “because you would rather have actual remote measurements at heights where you are going to be placing the turbines, than have to extrapolate what you think the wind speed may be based on



▲ ▲ FIGURES 5-6. Average wind speeds in the United States and Kansas at a height of 80 meters. Courtesy of AWS Truepower and NREL.

tower measurements. Over time, you will have a combination of these two. Eventually, as turbine heights get higher and higher, the industry will perhaps even align with the exclusive use of remote sensing to describe the resource at those heights.”

FORECASTING

The data required for forecasting, to build a model and do the analysis, “come from specialized agencies that have been doing this kind of forecasting for years and have built models and databases that are populated by on-ground readings,” explains Ngoroi. In this case, NREL’s published wind forecasting model is used. “They have been studying wind speeds using weather stations all over the country. I can also take elevation and slope data and use that as one of the inputs into the NREL wind forecasting model.” Additionally, Ngoroi would take climactic data, which is published by various agencies, to do 5-10-year forecasts. “Forecasting becomes almost an exercise in combining the geospatial data with datasets that are produced by NOAA or NREL.”

In Hawaii, where there is a strong push to deploy and use renewable energy because energy costs there are very high, there are many wind farms, large solar power installations, and rooftop PV panels. AWS Truepower has developed a system for Hawaiian electric utilities that helps their operators predict changes in power



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▲ **FIGURE 7.** Wind farm at The Cerro Gordo Project west of Mason City, Iowa. Photograph by Todd Spink. Courtesy of NREL.

▼ **FIGURE 8.** Aerial view of a wind turbine at the National Wind Technology Center. Photograph by Dennis Schroeder. Courtesy of NREL.

production in the near future (minutes to hours) from wind to solar. “If you don’t see that coming, it can lead to some critical issues when you are trying to balance those loads and maintain system integrity,” says Freedman.

Called the Solar-Wind Integration Forecasting Tool, or SWIFT, the system makes use of a network of remote sensing and point measurements that are being deployed by the Hawaiian Electric Company (HECO). It is a combination of SoDARs, a horizontal scanning LiDAR, and a radiometer. “The radiometer gives you profiles of the temperature and moisture, which is helpful to have when you are trying to make a forecast, especially if you are doing it in Hawaii, where there’s a scarcity of observational data.”

To estimate the speed and direction of winds that might be coming in over, say, the next 10-30 minutes, engineers combine data from horizontal scans at distances of 10 miles or more with weather forecasting models.

REAL-TIME APPLICATIONS

Forward-looking LiDAR sensors mounted on top of wind turbines and pointed upwind can measure the speed of the wind that will reach them in the next 2-10 seconds, says Clifton. Unlike data collected for later analysis, this application requires system engineers to couple the data stream in real time with the turbine’s control system.

While it will probably not become standard soon, “longer term, it is something that, as an industry, we are looking at to

understand the costs, the benefits, and the implications of doing this,” says Clifton. “As we get more information as an industry, then, possibly, the turbine manufacturers will offer it. NREL is doing a lot of research in this direction. We might also see people putting forward-looking LiDARs on top of wind turbines that are not coupled into the control systems but are being used to measure the performance of the wind turbine. That can be very helpful for warranty purposes and to confirm that the turbine is working as expected.” See **Figures 7-8**.

MEASURING WINDS OVER WATER

Satellites detect and measure surface winds by using scatterometers to measure wave movement. “The movement of small-scale waves can be correlated with the wind speed at a few meters above the surface,” says Freedman. “They are pretty accurate, probably within a meter or two per second, but it can give you an idea of what the wind climatology is well off shore. Once you get near the coast, the data are more questionable; therefore wind speed observations from satellite scatterometry is typically not really very good within 25 kilometers of the coast. SAR (synthetic aperture radar) does much better and gives a higher resolution much closer to the coast. However, that data is quite expensive and so it is problematic to use it for resource assessment.”

Wind speeds in the Great Plains are very high year-round, while Chicago, known as “the windy city,” is actually not significantly windier than any other U.S. city. Such general knowledge of wind conditions may be enough when choosing a location for a kite store, but the continued growth of wind energy will require increasingly detailed knowledge of local wind conditions in ever more areas of the United States, and around the world. ▲



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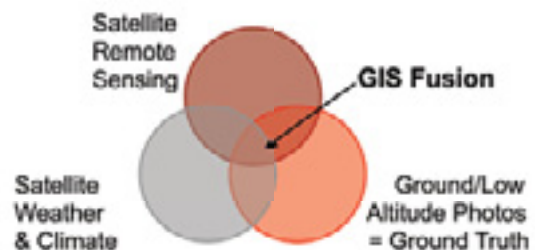


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□ The brightness of red tones are variations in the health of natural vegetation and lawns around undamaged homes. The more red in the image, the more green the vegetation on the ground. Where there is damage, dead vegetation is dark gray to ash gray in color, as are the destroyed homes. WorldView-2 color infrared image of Colorado Springs fires, 2-meter resolution, was taken June 28, 2012, provided courtesy of DigitalGlobe.



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