APOGEO SPATIAL

ELEVATING GLOBAL AWARENESS

Sustainability for Humanity

"It is not the planet, but rather *humanity* that is on the edge."

Hans-Peter Plag, PhD

"One day without civilian satellites would bring *chaos* to the global human society."

Filipe Duarte Santos, PhD

FORMERLY Imaging NOTES

PROUD MEMBER OF LMA LOCATION MEDIA ALLIANCE

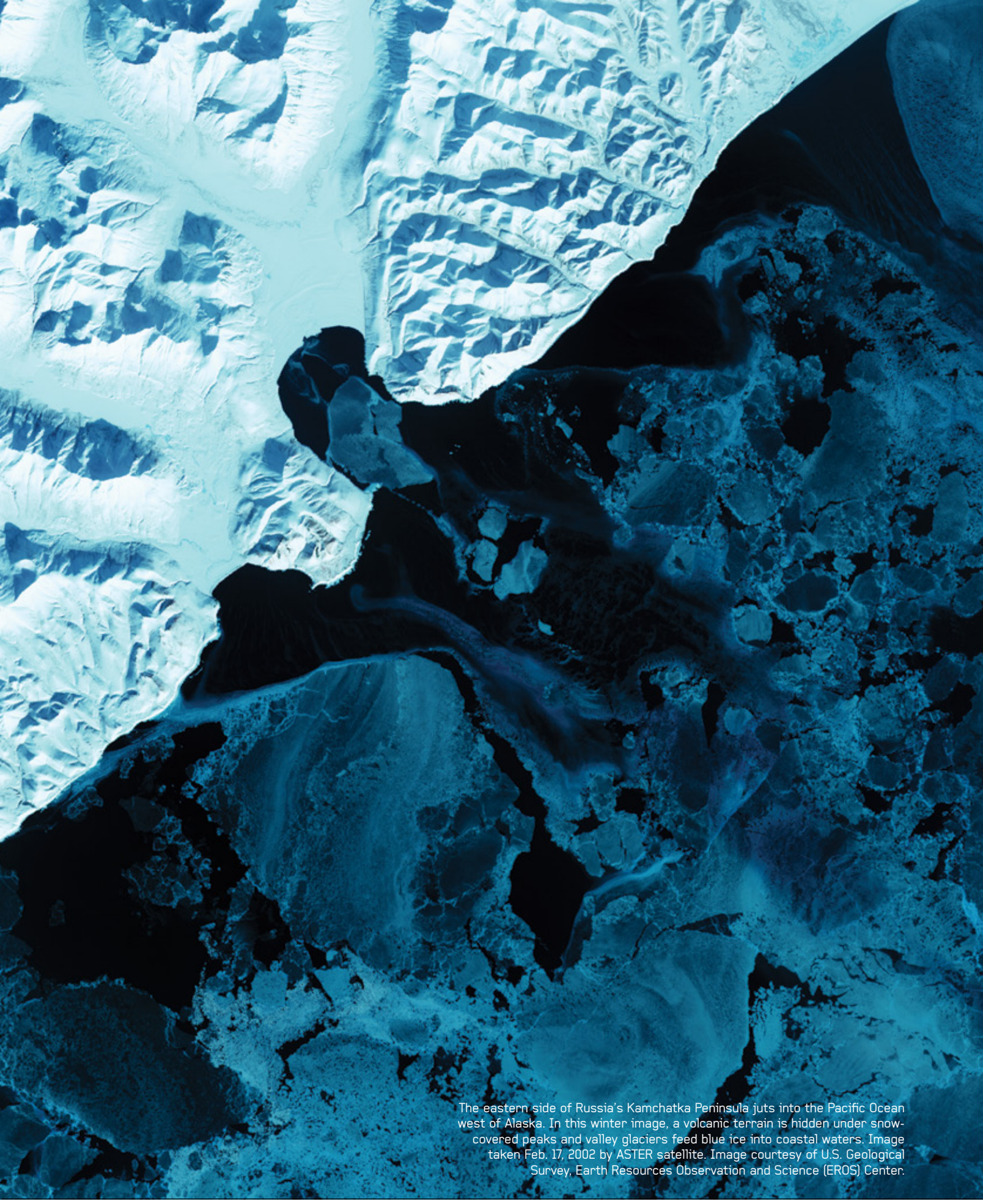
[Spring 2013 / Vol. 28 / No. 2]

Bora Bora image taken by Spot 6.

APOGEO SPATIAL

Apogeo 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.



The eastern side of Russia's Kamchatka Peninsula juts into the Pacific Ocean west of Alaska. In this winter image, a volcanic terrain is hidden under snow-covered peaks and valley glaciers feed blue ice into coastal waters. Image taken Feb. 17, 2002 by ASTER satellite. Image courtesy of U.S. Geological Survey, Earth Resources Observation and Science (EROS) Center.

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APOGEO SPATIAL

[Spring 2013 / Vol. 28 / No. 2]

Columns

Departments

Features

COVER IMAGE

Bora Bora, French Polynesia

BORA BORA IS AN ISLAND IN THE PACIFIC Ocean, in the western Leeward group of the Society Islands of French Polynesia, an overseas collectivity of France. The island is located about 230 km (140 miles) northwest of Papeete, the capital of French Polynesia on the island of Tahiti.

Bora Bora is surrounded by a lagoon and a barrier reef. In the center of the island are the remnants of an extinct volcano rising to two peaks, Mount Pahia and Mount Otemanu, the highest point at 727 m (2,385 ft).

The image is part of an article that provides an update on Astrium Services' GEO-Information division, which appears on page 46.

This gorgeous image was captured by Spot 6. © Astrium Services 2012. All Rights Reserved. ∧♂

APOGEO SPATIAL

Formerly Imaging Notes

[Spring 2013 / Vol. 28 / No. 2]

MISSION

Apogeo 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.

PARTNERSHIPS

Apogeo has partnerships with Secure World Foundation (www.swfound.org) and *Sensors & Systems* (www.sensorsandsystems.com).

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

EDITORIAL CONTRIBUTIONS

Apogeo welcomes contributions for feature articles. We publish articles on the remote sensing industry, including applications, technology, and business. Please see Editorial Guidelines on www.apogeospatial.com, and email proposals to editor@apogeospatial.com.

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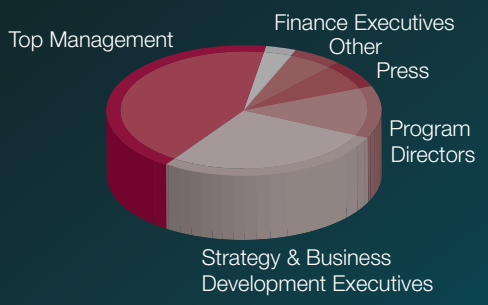
Thursday, Sept. 12

Enterprise User Forum:
- Location-Based Services
- Natural Resources
- Maritime

Defense & Security
Middle East & North Africa Focus
Leading High Resolution Operators

Friday, Sept. 13

Satellite Manufacturers
Civil Government Agencies
Innovative Operators
Data Distributors



Network • Benchmark • Strike Deals

A sample of confirmed speakers

Miguel Bello Mora, Managing Director, Deimos Group • **David Belton,** General Manager, MDA GSI • **Bernhard Brenner,** Executive Director, Astrium Services / GEO-Information • **Phil Cottle,** Managing Director, ForestRe • **Massimo Di Lazzaro,** ESVP Observation, Navigation & Science, Thales Alenia Space • **Gary Gale,** Director, Global Community Programs, HERE, Nokia • **Tom Ingersoll,** CEO, Skybox Imaging • **Ed Irvin,** VP International, Lockheed Martin Space Systems • **Ryan Johnson,** CEO, RapidEye • **Moongyu Kim,** VP, Satellite Image Services, SATREC-I • **Marcello Maranesi,** CEO, e-GEOS • **Michael Menking,** SVP of Earth Observation, Navigation & Science, Astrium Satellites • **Jane Olwoch,** Managing Director, SANSA • **Adrian Zevenbergen,** Managing Director, European Space Imaging

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APOGEO

No Boundaries from Space

Myrna James Yoo

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

Co-founder
Location Media Alliance

Owner
Blueline Publishing LLC

DEAR READERS,

Welcome to the realization of a dream: the relaunch of *Imaging Notes* magazine as *Apogeo*! We are working to provide you with a more compelling, visually stimulating read and to illuminate the world's most pressing problems through imagery and inspiring solutions.

Over a decade ago, I took an 18-month backpacking trip around the world, solo. As a Kansas farm girl, I found my worldview expanded in a way that I craved. It had an effect on me similar to that of seeing the Earth from space: It was truly permanently transformative. And I did not see boundaries.

Political boundaries exist, but can't be seen from space, or from a café in a mountain village, from the foot of a glacier, from a tree house near the ocean, from a local market, or from a World Cup game. What can be seen from traveling, and from space, is that we are all on this planet together.

Our ecosystem doesn't 'see' political boundaries either; it expands beyond them. Rivers flow through them, affecting everyone along the banks, regardless of nationality. Everything in our environment is interconnected–linked and co-dependent. *Apogeo* is founded upon this connectedness and mutual dependence.

What we can see from space are the man-made boundaries. We can see where we have carved up the land into cities and airports and highways and crop circles. We can see where we have scarred the land. We must maintain this macro view and take responsibility for what we are doing to our planet.

While traveling, I saw evidence of the need for change. One of the most profound experiences was witnessing the melting of Fox Glacier in New Zealand. As we drove closer to it, signs appeared, saying, "In 1975, the glacier was here," and then farther along, "In 1990, the glacier was here." Here is an excerpt from my journal, Feb. 28, 1999:

"Fox Glacier is melting! Wow! Chunks of ice as tall as buildings are falling into the cold roaring river of melting ice. It sounds like a gunshot, or cannon. The ice is so beautiful, curved like a cave at the main melting point, streaked in dark and light blues and whites...Global Warming..."

I knew I needed to learn more. The documentary *Chasing Ice* about National Geographic photographer James Balog's project "The Extreme Ice Survey" shows glacier melt using remotely controlled stationary cameras attached to rocks near glaciers around the world. It won the American Documentary Cinematography Prize at the 2012 Sundance Film Festival. *Apogeo* is using this power of imagery to tell stories, as well.

For our species to survive, we must keep this macro view–the satellite's perspective of our planet. *Apogeo* is communicating 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. With fresh, relevant insights from expert contributors, stunning visuals and clear examples of the technologies, those who make critical policy and business decisions about the world's resources will understand and be inspired by the visual and actionable power of remotely sensed data.

My professional journey has brought me here, and I could not be more grateful to be in a position to share this important information. While I am not a geospatial expert, I have become very passionate about this since my company acquired *Imaging Notes* nine years ago. As a career publisher, I know what makes a great publication, and have worked to apply that knowledge here.

Join us as advocates for Earth observations!

- **Subscribe: www.locationalliance.net/subscribe.**
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We cannot do this without you. Thank you!

Warmly,

Myrna James Yoo, Publisher

Myrna James Yoo (on right) and friends at the mouth of Fox Glacier, New Zealand, February 1999

Remote Sensing Training Course

Monitoring Global Ecosystems and Man's Impact

Who:
Resource analysts, planners, managers, and decision makers

Where:
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When:
Fall 2013

Duration:
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- *The Electromagnetic Spectrum*
- *GIS: The Integrating Tool*
- *Derived Knowledge-Based Information*

Sun-Earth System Overview

Monitoring Land, Water and Air Resources

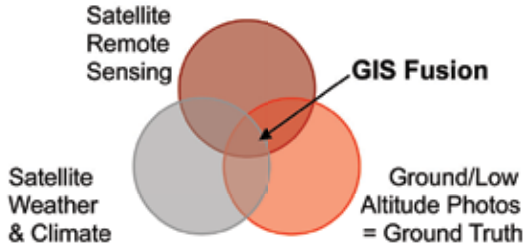
Getting Started in Your Work Unit:
- *A "Road Map" for Implementation*

The Trainers:

Dr. Delmar "Andy" Anderson
Del Consulting, Fort Collins, Colorado

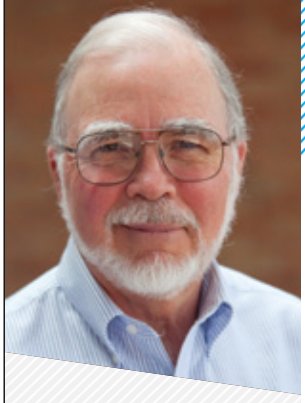
Robert Blevins
Owner, Meteorological Connections LLC, Gray, Tennessee

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.



Join us for an Evening Social!

Welcome to the Inaugural Issue of *Apogeo!*



Ray Williamson, PhD
Editor, *Apogeo*
Senior Advisor, Secure World Foundation
www.swfound.org

AS SHAKESPEARE ASKED, "What's in a name?" Well, for a magazine and other media, a name should convey what the magazine is about. It should also convey something about our aspiration to make the magazine the best it can be.

Apogeo, a word that combines the senses of moving out and of looking down at Earth, is very much an aspirational title. Imaging aircraft and satellites use their high altitude vantage points to look down in order to gain a synoptic view of our home planet. This sort of view is very much needed today, when humankind's effects on the environment are so deep and widespread.

The topics covered in this issue are certainly reflective of the new title and emblematic of the type of coverage we intend to pursue. *Apogeo* will maintain the same high standards of quality graphics and in-depth, timely reporting of key developments in remote sensing applications that *Imaging Notes* has provided, and that you, our readers have come to expect. At the same time, *Apogeo* will strengthen its coverage of the use of aerial and satellite imagery to support human and environmental security topics, to contribute to long-term sustainability of the planet, and of course, of people.

The periodical will also step up coverage of the sustainability of the space environment in recognition that the many benefits we derive from space systems need to be protected and maintained, for as Filipe Duarte Santos of UN COPUOS notes, "One day without civilian satellites would bring chaos to the global human society." Therefore, we will always advocate for Earth observations, including coverage of the space debris issue. Watch for an article about the Space Data Association in our Summer issue.

Both imaging technologies and the software needed for processing and interpreting imagery have greatly improved in the past few years. One of the most important developments, reported by Matteo Luccio, has been the marriage of GIS and remotely sensed data to create sharply defined analytical products that are much more than just a pretty picture. Read about "GIS + RS" on page 40.

Kevin Corbley highlights another important trend on page 46—how companies like Astrium are developing all products and services that their clients need, so clients can get end-to-end solutions from one company. One application is using their radar assets for maritime security.

In recent years, experts have become increasingly convinced that humankind needs to become better stewards of the environment and to actively manage the planet in order for humans to continue to thrive. *Apogeo* plans especially to emphasize the utility of remotely sensed data to support Earth sustainability. Dr. Filipe Duarte Santos' thoughtful article on page 30 of this issue provides a concise overview of the sorts of topics that we plan to bring to the magazine, from analysis of climate and global change to the insecurity of our food, water and energy.

In addition, we have formed the Location Media Alliance (www.locationalliance.net) in order to bring you publications covering the ecosystem of remote sensing, from data collection and processing (*Apogeo* and *Sensors & Systems*) to end users (*Informed Infrastructure* for city planners and the built environment, *Asian Surveying & Mapping* for that geographic region of the world, and *LBx Journal* for the business user). The quarterly themes of food, water, energy and security will be covered in all five publications. In this issue, water tracking via satellite is covered on page 54.

We truly hope you enjoy and find compelling this inaugural issue of *Apogeo*. It is our pleasure to bring it to you.

Sincerely,

Ray Williamson, PhD, Editor

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

FEBRUARY	MARCH	APRIL
Iceland Announces that Geo-Information is Free http://bit.ly/12SeXFY	John Deere Adds Array of Environmental Sensors to Field Connect http://bit.ly/Yf01SY	Advanced Defense Technologies Targets UAV Technologies at Precision Agriculture Applications http://bit.ly/186bZAb
senseFly's New eBee Drone Demonstrates its Mapping Capabilities in the Swiss Alps http://bit.ly/10lzMEG	Water Issues Drive Precision Agriculture Solutions http://bit.ly/11PPTNG	Study Forecasts Bright Future for GIS Industry in Australia http://bit.ly/17rqSMf
Statewide GIS License from Esri Supports Maryland's STEM Goals http://bit.ly/ZX8BQB	2012 Satellite Launch Results: China and France Advance http://bit.ly/Y6YGLz	Precision Agriculture Improves Farming Efficiency, Has Important Implications On Food Security http://bit.ly/ZQeIdj
Overwatch's LIDAR Analyst 5.1 Software Delivers New High-Resolution 3D Imagery and Analytics http://bit.ly/10lA2n3	NOAA Assumes Full Operational Responsibilities of Environmental Satellite http://bit.ly/17rqm0t	NASA Imaging Sensor Prepares for Western Wildfire Season http://bit.ly/ZW5Obj
Microsoft Introduces 210mm Lens for UltraCam Eagle http://bit.ly/167xwsR	Postponed: The National Map 2013 Users Conference and USGS Community for Data Integration (CDI) Workshop http://bit.ly/11PQe2O	Interactive Map of the Arctic http://bit.ly/1525JL8
Trimble Acquires Penmap Software to Expand its Applications for the Survey and Cadastral Markets http://bit.ly/ZVN9MF	Pan-European Open Data Available Online from EuroGeographics http://bit.ly/10M8ONQ	Mapping as a Platform on Full Display at the Esri UC http://bit.ly/18baI87
Google Unveils Google Maps for Education http://bit.ly/11NUFfP	Amphibian Study Shows How Biodiversity Can Protect Against Disease http://bit.ly/12EZMyU	Esri Chief Scientist, Dawn Wright, PhD, Receives Distinguished Teaching Honors http://bit.ly/18baPAA
Hot Spot for Developers, Esri Lavahouse Makes SXSW Debut http://bit.ly/11NUKA0	U.K.'s TechDemoSat-1 to launch Q3 2013 http://bit.ly/17rqAVv	USGS Launches Interactive Online Biodiversity Map for the Nation http://bit.ly/11PQZJg
Interior Prepares to Conduct Landsat 8 Scientific Programs After Successful Launch of Latest Earth-Observing Satellite http://bit.ly/YeCMsd	Booz Allen Hamilton to Provide Specialized Scientific Research to the National Geospatial-Intelligence Agency's InnoVision Future Solutions Program http://bit.ly/ZcJf1W	Lamborn Introduces, "Map It Once, Use It Many Times" Act http://bit.ly/ZI2i8U
CASA's Prof. Michael Batty Awarded the "Nobel Prize" of Geography http://bit.ly/18atA7c	GOCE Satellite Detects Japan's Tohoku Earthquake http://bit.ly/Y6Z90q	Crowd-Sourcing the Nation: Using Volunteers for Enhanced Data Collection http://bit.ly/18bb3rp

COLOR-CODED CATEGORIES:

- Corporate News
- Product News
- Policy/Research
- Global Change
- Environment
- Food/Agriculture
- Ocean
- Energy
- Security

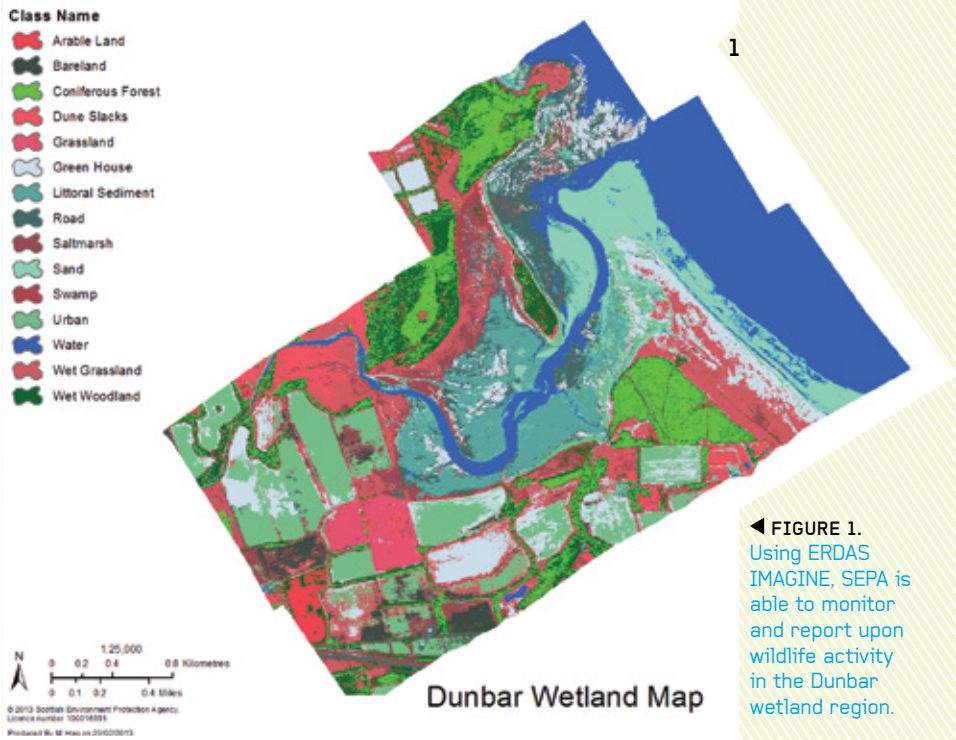
Environmental MONITORING

Several U.K. Organizations Use Geospatial Solutions

BY AMY ZELLER, SENIOR PRODUCT MARKETING MANAGER
INTERGRAPH'S GEOMEDIA SMART CLIENT / INTERGRAPH CORPORATION
HUNTSVILLE, ALA. / WWW.INTERGRAPH.COM

Organizations responsible for environmental monitoring, especially when it comes to 'smart development' in environmentally sensitive areas, are increasingly using some powerful geospatial data, tools and processes to ensure minimal impact.

The sound study, assessment and monitoring of natural resources and habitats is of the utmost importance in ecosystem management. In the United Kingdom, a high priority has been placed on managing natural resources, and maintaining a balance between sustainable energy sources and a sustainable environment in which to live. It is understood that a healthy, properly functioning natural



◀ FIGURE 1. Using ERDAS IMAGINE, SEPA is able to monitor and report upon wildlife activity in the Dunbar wetland region.

Sensors & Systems

Editor's Note:
This article was previously published in our partner publication, *Sensors & Systems*.

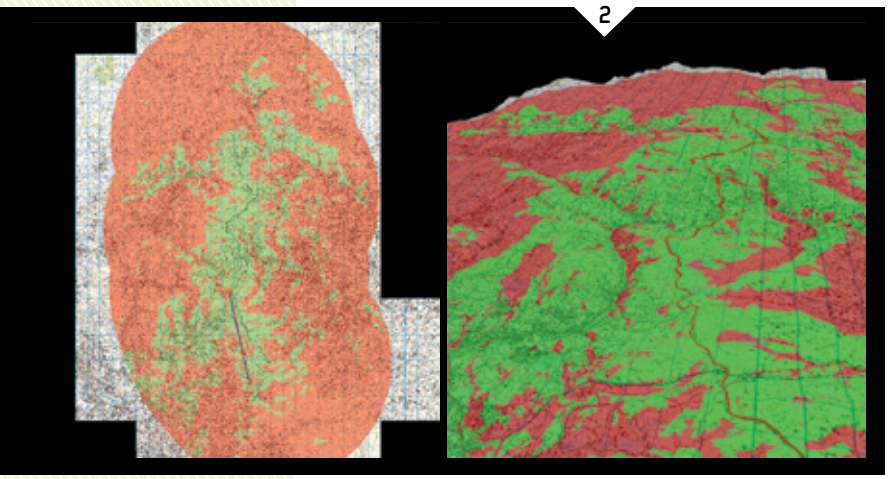
environment provides the foundation for sustainable economic growth, prospering communities and personal wellbeing.

The Department for Environment, Food & Rural Affairs (DEFRA) in the U.K. is the government department responsible for policies on environmental regulation and sustainable development. DEFRA reflects U.K. government key priorities to:

a. Support and develop British farming and encourage sustainable food production;

b. Enhance the environment and biodiversity to improve quality of life;

c. Support a strong and sustainable green economy and thriving rural communities that are resilient to climate change.



▲ FIGURE 2. Natural England was able to develop enhanced 3D visualization using ERDAS IMAGINE Virtual GIS.

In order to ensure that these criteria are effectively met, many agencies within the U.K. are tasked with preserving the natural environment, and have become increasingly involved in the use of satellite and aerial imagery, infrared and LiDAR datasets. All of these data products are highly effective in mapping, monitoring change and supporting the assessment of natural habitats.

Environmental organizations and contractors now collect and store gigabytes and even terabytes of geographic data, which must be stored and disseminated properly to the right technical experts for analysis such as vegetation health detection, slope stability risk analysis and species change. Through these customized and highly specialized spatial models, experts are able to understand clearly the anthropogenic impact to our environment.

Some aerial surveys involve the collection of thousands of aerial images in one study. To manage these massive volumes of data, environmental monitoring organizations in the U.K. are turning to comprehensive data management, analysis and delivery solutions. These solutions must enable the organization to create a catalog of human-understandable metadata, where data can be easily searched, discovered and securely disseminated to the proper end users and technical experts.

Along with serving imagery very fast, these solutions should also provide the ability to dynamically edit data, perform analytics and extract information products on demand. Organizations can use next-generation software for performing advanced remote sensing analysis and spatial modeling to create new information. A key benefit of these kinds of solutions is that users can visualize the results in 2D, 3D, movies, and on cartographic-quality map compositions.

IMPACT OF WIND FARM DEVELOPMENT

The environmental impacts of wind farm development are always a major consideration when countries are exploring alternative energy sources.

The U.K. is currently a world leader in offshore wind power generation. Wind farms tend to be ideally suited for expansive regions and coastlines where wildlife is abundant. While a good alternative source of energy, they are not without their impacts to the wildlife populations in those areas.

Understanding the environmental impacts of development is a vital step in moving forward with energy solutions. To perform proper assessment and ensure minimal impact in site selection, a number of organizations are already using geospatial solutions and imagery analysis for natural habitat evaluation and site selection.

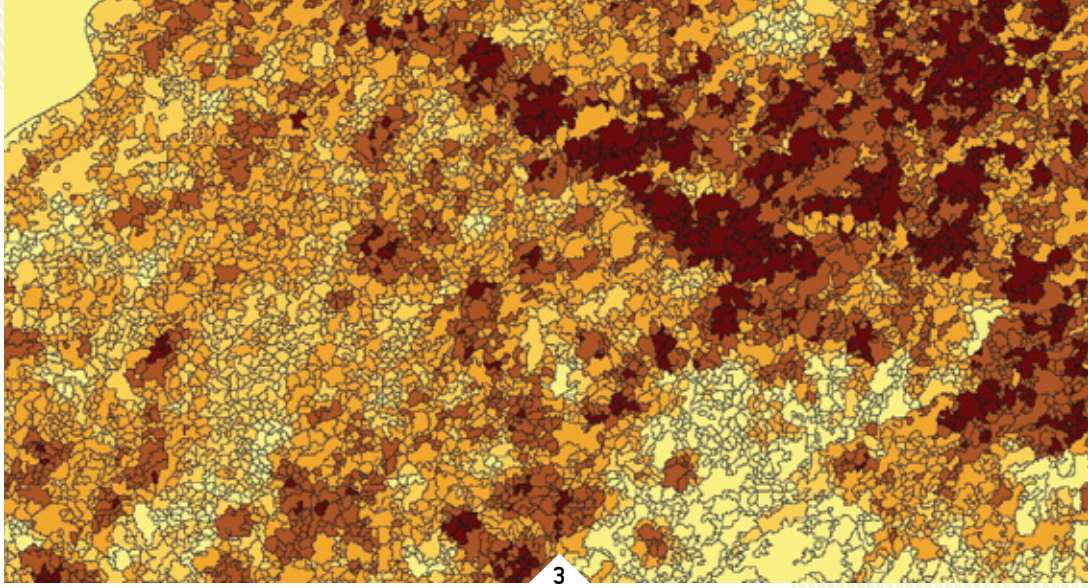
For one such project, APEM Ltd. is monitoring bird populations living in areas zoned for potential development, or in areas already developed for wind power generation. APEM specializes in freshwater and marine ecology assessment using aerial surveys.

Using a proprietary algorithm for identifying and enumerating birds from aerial photographs, they have collected tens of thousands of images. To date, APEM have amassed over 87 Terabytes of aerial photography using 4 Leica RCD30 medium-resolution cameras on five aircraft.

In order to handle this massive quantity of data, core management and delivery capabilities are required. Key solutions from Intergraph have been used to enable the customer to organize and disseminate data to the

technical analysts who examine and count birds captured in every image. Other Intergraph solutions are also used for data authoring and generating terrain models of the actual bird habitat.

By using these products, APEM is able to understand and process massive amounts of aerial data required for supporting the planning and development, as well as monitoring the impact of wind farms in this region.



▲ FIGURE 3. ERDAS IMAGINE is used for the mosaicking, stacking, creating segmentation, and the NDVI indexing of a bog in Scotland.

OTHER ENVIRONMENTAL MONITORING USES

Through our U.K. partner Sterling GEO, Intergraph has been able to implement solutions in other unique ways. For example, the Scottish Environmental Protection Agency (SEPA) monitors and reports on the state of Scotland's environment. The natural environment makes up 80 percent of Scotland's land mass and is home to more than 1,000 different species of birds living in large wetland areas. Correspondingly, SEPA deals with massive volumes of data regarding various bird species and wildlife habitat. SEPA uses Intergraph solutions and has been able to effectively assess and monitor the country's natural wetlands. See *FIGURE 1*.

In addition, Natural England is an organization that provides environmental consulting to the U.K. government. They recently ran a pilot project looking at line-of-sight analysis along the major walks of England.

The organization's applications team used Intergraph solution ERDAS IMAGINE to analyze a 10km stretch of the Pennine Way, ultimately creating a virtual walker 2m high and measuring what they could see, based on a 5m Digital Elevation Model. From there, the group collated the data into a single GIS layer and visualized it in 3D. What is unique about this use case is that the whole process took less than 2 hours, including computation time. See *FIGURE 2*.

Scotland is renowned for its areas of outstanding natural beauty and rugged landscape. The Scottish Natural Heritage is funded by the Scottish Government to promote and care for the country's natural environment. The nation's peatlands and bogs provide a natural water source that help maintain steady flow rates in salmon rivers, sheep grazing and recreation areas. The organization conducts in-depth vegetation analysis to properly monitor these areas, and runs ERDAS IMAGINE to utilize unique mosaicking, stacking and powerful segmentation capabilities for environment classification and assessment. See *FIGURE 3*.

FUTURE OF ECOSYSTEM MONITORING

Pressures of an expanding global population, increasing energy demands and the growing responsibility we must take to manage our environment drive us to create smart and sustainable policies that minimize the impacts of development on the natural world.

Sensitive environmental regions of the world have become beacons—sign-posts even—to warn us of the impact we humans can have if development is not kept in check. Now more than ever, it is our responsibility to constantly monitor the impacts of our man-made 'improvements,' and ensure that our activities within nature do as little harm to the environment as possible. Whether we're overseeing the wetlands and peatlands of Scotland, or examining nesting bird populations whose mating regions are being threatened by man, detailed analyses help us to understand where we must modify our activities in these areas, and furthermore how we should advise governments and inform useful policy-making.

Accurate, detailed geospatial data is now more available and important than ever. New lifecycle management solutions combine best-in-class products with enterprise geospatial information management, enabling environmental monitoring organizations to simplify and control how data and workflows are maintained, shared, accessed and applied. This ultimately enables rich data stores to be effectively used in ways that directly impact smart development.

As the world changes, the right geospatial data management solutions will provide key insights for sustaining the health of our planet in the near and long term. ∧♂

Location SmartBrief: Business Game Changer

LBx JOURNAL

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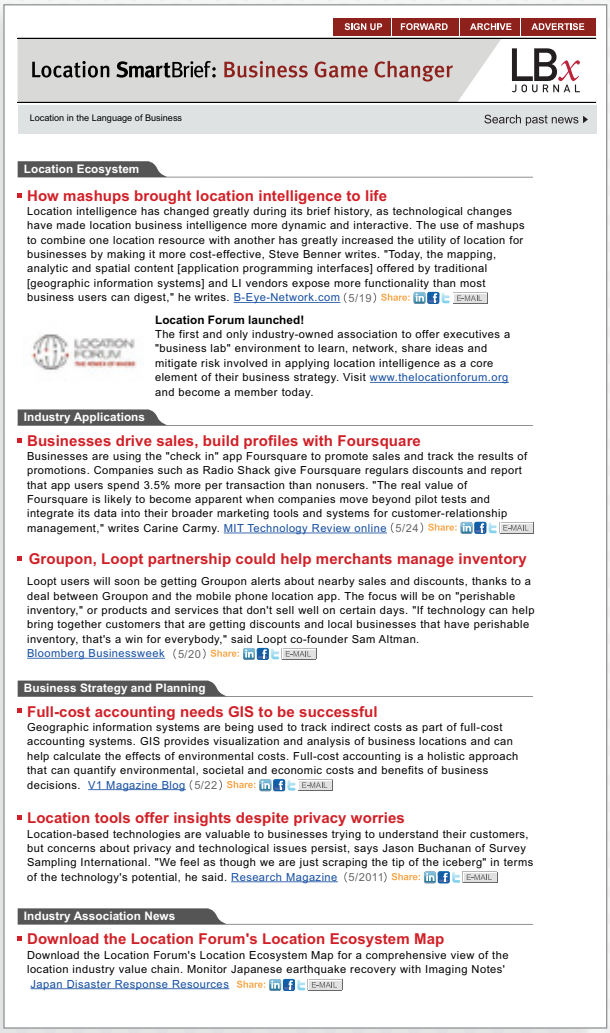

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QUARTERLY LOCATION BUSINESS NEWS

Here are the most interesting or important articles from the web, according to *Location SmartBrief* readers:

LOCATION ECOSYSTEM

1. **Microsoft's GeoFlow tool creates vibrant maps with Excel data** — April 24, 2013

   The new GeoFlow tool for Microsoft Office Excel 2013 allows users to visualize spreadsheet data geographically by mapping it into columns, heat maps or bubble visualizations overlaid on Bing Maps. The tool also allows users to correlate data from various spreadsheets and can animate maps to show the passage of time. http://bit.ly/Ztdy4H

2. **Why the food industry needs to embrace precision agriculture** — March 16, 2013

   The time has come for wider adoption of precision agriculture technologies as customers show greater concern about the quality of food, while processors worry about consistency and providing transparency to the public, Matt Ball writes. New machinery commonly has the necessary equipment on board and the costs have come down as well. http://bit.ly/15f2Eas

3. **Geo-targeting helps marketers drive local business** — April 3, 2013

   Geo-targeting technology customizes searches using the location of mobile phones or other location-enabled devices, giving small-business customers a more personalized experience. "No two search experiences will be alike. Search results will be specifically based on customer location, previous search history, and preferences. Having a better experience will lead to better sales," Flekel writes. http://bit.ly/113dZsT

INDUSTRY APPLICATIONS

1. **Which states and counties have the highest taxes?** — April 17, 2013

   Tax Day has come and gone. This analysis features interactive maps that look at how states and counties stack up against one another when it comes to income and property taxes. There is also a map that shows the ZIP codes throughout the U.S. where residents were most likely to use tax software to prepare their returns. http://bit.ly/15f32FV

2. **Survey: Location-based services are a priority for insurers** — February 27, 2013

   An Accenture survey found that 42% of insurer chief information officers rank mobility among their five biggest priorities, with 79% expecting the technology to enhance revenue. Location-based services topped the mobile-priority list of nearly half of CIOs, the survey found. "It's encouraging that companies are embracing the importance of mobility but they need to go further by identifying the top areas for mobile deployment," Accenture's Jin Lee says. http://bit.ly/YugL93

3. **Esri leverages unique space for mapping gurus at SXSW** — March 13, 2013

   This year's South by Southwest Interactive Festival was as much about interactive media and technology as it was about music. Software firm Esri commandeered a unique venue in Austin, Texas, to connect developers, hackers, entrepreneurs and executives with its geographic information systems mapping solutions. "GIS has been used for a long time in natural resources and government... But commercial companies are starting to use it more and more, for things like, 'Where's the best place to locate a store?'" explains Esri Chief Marketing Officer Linda Hecht. http://bit.ly/13SwzRh

BUSINESS AND STRATEGY PLANNING

1. **Esri's Maps for Microsoft Office brings data points to life** — April 10, 2013

   Esri's Maps for Microsoft Office allows users with access to ArcGIS Online to transform Excel spreadsheet data into an interactive map within the application. Maps of customer addresses or distribution points can be generated quickly, Karen Richardson writes. "Using this, I honestly created a map within minutes. Nothing could have been easier," Mike Cooper of Leica Geosystems said. http://bit.ly/17RrAm3

2. **Facebook working on app to track mobile users** — February 6, 2013

   Facebook is developing a location-based application that would track mobile users as a way to help them find their friends—even when the Facebook app is closed, according to a Bloomberg report. Another report asserts that Facebook issued—and quickly rescinded—a similar app called "Find Friends Nearby" in June 2012. Separately, Facebook announced that as part of an agreement with the Better Business Bureau, it will become more forthcoming about its targeted advertising efforts. http://bit.ly/YQ5BVD

3. **Putting a (woman's) face on the location industry** — March 13, 2013

   Women are naturals for the location industry, as "location-based thinking, applications, and technologies are so naturally aligned with the way women think and view the world, but they remain in the minority in the field," Natasha Léger writes. Léger has profiled 18 women in the industry who are making advances in areas like location-based services and mobility, 3D Big Data management and mobile marketing. http://bit.ly/11HNTq8

LBx JOURNAL

LOCATION IN THE LANGUAGE OF BUSINESS

Women In Location

» READ THE FULL FEATURE AT HTTP://PROMO.LBXJOURNAL.COM/WIL.HTML

Apogeo's sister publication, *LBx Journal* published a Special Feature on Women in Location, which uniquely tells the story of location-based technologies like never before. You may recognize some of the women featured above. Read more about them and how their views of the role of location in society, the economy, and the world can inspire us all at http://promo.lbxjournal.com/WIL.html.

PROUD MEMBER OF

LMA
LOCATION MEDIA ALLIANCE

I HAVE BEEN CO-FOUNDER AND EDITOR OF *LBX JOURNAL* for four years now and I have become increasingly concerned by the visible lack of women in the location industry. How many conferences do you attend where women are 10 percent or less of the audience, or where women represent less then one percent of the speakers, and webinar participants are mostly men? Company Boards of Directors and management teams are mostly men. And the list goes on. One male senior executive of a very sizable location company even observed that "the lack of women in the industry is just not healthy."

While the gender disparity is stark, it is not unusual in the technology field. Women have not naturally gravitated towards engineering, science, and technology for a variety of social, cultural and personal reasons. But what was particularly gnawing at me was the fact that location-based thinking, applications, and technologies are so naturally aligned with the way women think and view the world because of the holistic nature of spatial analysis. So if it's so natural, why aren't there more women in the space, or why aren't they visible? That set me on the path to finding dynamic women from across the location ecosystem at varying stages in their careers to put not only faces, but women's faces to the various aspects of location.

My goal, as I told all of the women profiled, was to produce a very inspiring feature on Women in Location. I think we accomplished that. But I think we accomplished even more. Not only are the women in this feature inspiring, their views on location inspiring, their roles in promoting the importance and development of location inspiring—especially their unique ways of executing their individual responsibilities—but collectively, they have expressed the very human aspects of location.

They have personified the ecosystem of information that stems from understanding the power and role of place in our lives. Location-based thinking and technologies are not just about the ROI, new products, revenue goals, cost cutting, and targeting consumers to buy more stuff, which have been the focus of a great deal of our reporting these last four years; they're about the human connection we all have to 'place,' and what that means to us as individuals—how we see the world, and how we behave in the world—for better or worse.

The women profiled in this feature represent an astounding breadth of experience from deep science to geospatial expertise to business savvy in various roles, including engineering, sales and marketing, finance, and management. They put faces, personalities, and visions to such areas of location as 3D big data management, environmental and atmospheric modeling, location-based services and mobility, mobile marketing and targeted advertising, SmartCities, geo-accounting and geo-business intelligence, and to such industries as retail, nonprofit, consulting, and communications. Looking at location through this broader, more diverse lens, for me, elevates the location industry to a new level.

I would be remiss in not pointing out that, while they were not profiled in this feature, women head up the majority of the geospatial publications, including Tracy Cozzens, Managing Editor of *GPS World*, Jane Elliot, Publisher of *Directions Media*, Adena Shutzberg, Executive Editor of *Directions Magazine*, Myrna James Yoo, Publisher of *Imaging Notes* and *LBx Journal*, and myself included as Editor of *LBx Journal*. There are also many more women whom we look forward to profiling in our next feature.

Read on for the creativity, authenticity, and pure passion that emanates from these incredible Women in Location...

Natasha Léger
Co-Founder, Editor

Long Term Sustainability of Space

PRACTICES FOR THE FUTURE: A REPORT FROM THE NATIONAL SPACE SYMPOSIUM

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AMIDST ALL THE ATTENTION FOCUSED on sequestration and security at this year's National Space Symposium, it was an interesting surprise to hear the idea of space sustainability emerge again and again. From formal presentations to hallway conversations, it was clear that the long term sustainability of space activities was a concern that has very much permeated the thinking of those responsible for planning and creating the future of the space sector.

At a time of great competitive pressure and intense policy debate, one area of broad agreement among government officials, industrial leaders, space entrepreneurs, academics, and interest groups was that our ability to continue benefitting from assets in Earth orbit faced some serious and imminent challenges. Importantly, these concerns were not confined to prepared remarks and public statements. Private conversations about business opportunities were peppered with thoughts about sustainability. Discussions about new space ventures were quickly linked to questions about how to avoid creating new debris and how to manage end-of-life disposal. Sustainability, it appears, has gone mainstream.

Even the generation gap that has seemed to characterize some of the early discussions of space sustainability was missing. It was mentioned as frequently by the veteran space professionals attending the symposium as it was by the younger ones attending the Space Generation Fusion Forum that preceded it. Similarly, it was as common a topic among the representatives of countries recently involved in space activities as it was among those of countries that have been there since the early days of the space age.

Some of the frequently mentioned challenges to sustainable use of space were ones that have received a lot of attention in these pages and elsewhere: space debris, space situational awareness, space traffic management, and radio frequency interference. But there were also themes that have more recently emerged as credible parts of the discussion, such as on-orbit servicing as a means of extending the useful life of space assets, or of aiding in their responsible disposal. The inevitability of cooperation was mentioned so often that one would have thought speakers were working from a common list of talking points. And several participants seized the opportunity to hammer home the fact that to be truly sustainable, space activity had to solve the problem of affordability.

Although a large number of panels and speeches at the symposium included references to sustainability, one panel was specifically dedicated to the subject. Entitled "Long Term Sustainability of Space - Practices for the Future," it pulled together representatives of industry, academia, and government to explore the many meanings that sustainability has acquired as the sector confronts the challenges of keeping space open for applications, innovation, and development.

Jim Simpson from Boeing Space and Intelligence Systems went straight to the heart of the affordability issue mentioning several initiatives that have reduced the cost of recent payloads, while noting that each one of these steps toward progress was an important "event," where what the system needed was

a "routine" of cost-reducing best practices. He saw a future where leveraging international and commercial partnerships and effective cost management would be essential to making space benefits more affordable.

Kay Sears, President of Intelsat General, noted that the health and stability of space was essential to her firm's continuity of service and was a major incentive behind Intelsat's leadership and involvement in the creation of the Space Data Association (SDA). Providing a very concrete example to the international and commercial cooperation that Simpson had invoked, Ms. Sears described how SDA added critical maneuvering data to the JSpOC (Joint Space Operations Center) catalog information to deliver greatly improved conjunction analysis without compromising proprietary data. She also addressed how automation had helped Intelsat address affordability issues by creating a system where seven people were able to control a fleet of 85 spacecraft.

International perspective on the panel was provided in part by Dr. Kazuto Suzuki who noted the growing interest in space activities among Asian countries and the growing likelihood that international understanding of best practices will converge during 2013 as various broad-based discussions on subjects such as the proposed International Code of Conduct (ICoC) and the quest for Transparency and Confidence Building Measures (TCBM's) proceed globally.

Representing the European External Action Service, the diplomatic arm of the European Union, Ambassador Jacek Bylica outlined the impact the ICoC could have on sustainability even though it would not be a legally binding instrument. He stressed the importance of the consultative process in defining best practices since the effectiveness of a code of conduct depends on how broadly countries accept ownership of its principles.

Following the presentations, a large number of questions were directed at the panel ranging from technical issues in controlling costs to broad concerns about the likelihood of international participation in space situational awareness. On the latter point several panelists noted that the necessary infrastructure was already in place around the world and that what remained was to find agreement on how to share the data. A number of questions followed up on the international theme to ask about how China and India could be better integrated into the discussion of sustainability with the response that as both countries demonstrate more and more success with their space programs, their self-interest in sustainable space also grows.

Of special importance to all of us with a strong professional interest in Earth observation and remote sensing, the concluding remarks from this panel recalled themes that had been raised in earlier discussions of disaster management and economic development: space assets had permitted many developing countries to substitute space-based technologies for terrestrial infrastructure at great savings in cost. These countries, representing the "Other Three Billion" people who trail the rest of Earth's human population in economic development, could see their entire growth strategy crumble if the use of space were to become unsustainable.

> "Several participants seized the opportunity to hammer home the fact that to be truly sustainable, space activity had to solve the problem of affordability."

Ultimately we return to the theme of affordability. For space to be sustainable, industry has to manage costs, government has to foster a stable policy environment and minimize procedural obstacles, the international community needs to cooperate to minimize the high and unpredictable costs of debris-ridden orbits and chaotic traffic management, and an entire space sector has to ensure that not only current users but also future ones can have sustained access to the benefits of space. ∧☌

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Running in Fog

FINDING A SAFE OPERATING SPACE FOR HUMANITY

ON A BRIGHT SUMMER DAY IN 1979, four people started a hike from the southern coast of Iceland near Skógar into Thórsmörk. The day before, a strong storm had hit the island and cleared the air. By noon, the group had reached the height of the pass between two glaciers. Fog started to form and soon it became very dense. They were descending over a smoothly declining snowfield. After some time, the slope increased to a challenging level.

I was one of the group of four. The fog was one of the densest fogs I have ever experienced, with almost no visibility. Rather suddenly, I felt very uncomfortable, with a sense of danger starting to develop in my body, and I argued with the group that it was too dangerous to continue. Finally we decided to hold and prepare for a long night on the snowfield. This avoided disaster: The next morning we realized that we were only a few meters away from a sharp edge at the top of a 800-meter near-vertical drop into the magnificent valley of Thórsmörk. Hiking in the dense fog on the previous day, we had little idea what we were heading towards. The spectacular landscape carved by ice and water out of the sequence of hard lava and soft ash layers would challenge any hiker with sharp edges and deep drops. Adhering to a diffuse sense of danger had saved our lives.

Nick Mabey[1] and others suggest that our home planet is "on the edge." True, our planet is on a trajectory of great changes. As James Syvitski explains,[2] global change research has shown that we are in "an epoch of our making," the Anthropocene, in which we humans have risen to be the dominating force in the surface dynamics processes impacting ocean and atmospheric composition, biodiversity, and, eventually, climate. The notion that we are pushing the planet on the edge is thus not too far-fetched. However, the fact that we have moved from the passenger seats in the back of the bus to the driver seat is a game changer. We have to learn to drive, or we as humanity, not the planet, will fall into one of the abysses on both sides of the safe road.

The planet has gone through many transitions and phases in its history. Many of the stationary epochs would not have been accommodating for humanity and our civilizations. This brings us to the concept of a "safe operating space for humanity," introduced by Johan Rockström and others:[3] within the space of all possible states of our planet, there is a subspace that is safe for us. We better make sure that we do not push the planet outside of this subspace.

As far as we know, there are a few global boundaries that define this space, and Rockström and his colleagues identified nine: climate change, ocean acidification, stratospheric ozone depletion, nitrogen and phosphorus cycles, global freshwater use, change in land use, biodiversity loss, atmospheric aerosol loading, and chemical pollution. These boundaries may turn out to be like the edge we met on our hike in Iceland—an edge that separated life from death.

Editor's Note:
A related story about the Sustainability of Space Systems appears on page 30.

With this boundary concept, we see that it is not the planet but rather humanity that is on the edge. Another similarity with our hike on Iceland is the fact that not all of the nine boundaries are quantified and we are in a fog keeping us from seeing the edge. In Iceland, we did the right thing when we halted during our hike, but humanity's addiction to growth, including economic growth and profit at any cost, keeps us driving on without sufficient sight of the road and the edges.

> "It is not the planet but rather humanity that is on the edge."

Our re-engineering of Earth's surface processes and climate system could well push the planet on a run-away trajectory to a completely new homeostasis far off from the state that allowed humanity's global civilization to emerge. James Lovelock stated that many feedbacks in the Earth's climate system are currently positive, leading to increasing speed of changes.[4] This is not unlike a run-away truck on a steep downward slope. Where the run-away system will end up depends on where the feedbacks turn negative. Lovelock thinks that this could be at a stage with global temperatures being 5 degrees Celsius warmer.

What are the consequences of being on a run-away planet? One consequence will be an impact on the carrying capacity of the planet. Lovelock estimates a capacity of one billion people for the 5-degree-plus planet.[4]

As of October 2011, there are seven billion people on the planet, and currently, we live a lifestyle with a footprint of 1.5-2 planets. The lack of sufficient resources in large geographical regions and the greedy hunger for resources in other regions are already fueling wars, migration and terrorism. With a decrease in carrying capacity and a continuous growth of our numbers, this can only worsen. Soon, our lifestyle may have a footprint of 5-10 planets. There is little that could prevent this from resulting in a period of global social unrest and unprecedented wars. Our children are facing a global nightmare.

What metric is supporting the notion of a run-away planet? In a recent *Science* publication, Shaun Marcott and colleagues showed that at the beginning of the last century, the global temperature was close to the minimum of the last 11,300 years, while today's value is almost the maximum in this time span.[5] Thus, the change during the last century was the largest century-scale change in more than 10,000 years, and it was on the order of the total range in this time window.

◀ FIGURE 1. Humanity, on the edge.

▲ FIGURE 2. Thórsmörk, Iceland, 1979. Image courtesy of Hans-Peter Plag.

> Our experience of a stable sea level... has fooled us into believing that sea level is basically stable. There is no rational basis to assume that sea level will remain stable in a time where the speed of temperature changes is larger than ever.

Together with a colleague, we estimated how much temperature normally changes within one century. We used temperature data for the last 800,000 years, and found that within a century, temperature changes were always less than +/– 0.4 degrees C.[6] Thus, the change of +0.7 degrees during the last century already exceeds the maximum century change observed in the past. The potential increase of 4-5 degrees during the 21st Century would exceed the maximum change of the past by a factor of 10.

Interestingly, the distribution of century-scale changes in global sea level is bounded by +/– 6 meters per century and changes of +/– 2 meters per century are very common. The last 7,000 years were very unusual with sea level changes limited to a few centimeters per century. The exceptional stability of sea level on a global scale and locally in many coastal areas allowed humanity to benefit from coastal settlements. Our experience of a stable sea level throughout the period of recorded civilization has fooled us into believing that sea level is basically stable. However, there is no rational basis to assume that sea level will remain stable in a time where the speed of temperature changes is larger than ever.

One great transition of humanity is the one from a rural to an urban species, and most of our rapidly growing urban centers are in the coastal zone. With this development continuing, a highly variable sea level will challenge our civilization to its core. At the same time, we have allowed our cities to sprawl into hazardous areas with the consequence of increasing human-made disaster triggered by natural hazards.

The planet is on its way to a state unfavorable for us as a global civilization. More importantly, the speed of the transition is most likely exceeding the adaptation capabilities of large parts of the biosphere. The combination of us vastly killing off species and climate change exceeding the adaptive capabilities of many ecosystems is rapidly reducing biodiversity. Yet many of us still believe that we will remain unscathed.

Our situation is like the one on the Titanic after

Bio:

After some years as a carpenter, Hans-Peter Plag studied mathematics and geophysics in Berlin, where he obtained a PhD in Natural Sciences in 1988. He has held positions at universities and research institutes in Germany, the U.K., Norway, and the U.S. He is currently Professor at Old Dominion University, and Director of the Climate Change and Sea Level Rise Initiative, Norfolk, Va. His main fields of expertise are in sustainability, global change, local to global sea level changes, Earth system dynamics, solid Earth geophysics, and space geodesy. Current main professional activities are related to the Group on Earth Observations (GEO), which is implementing the Global Earth Observation System of Systems (GEOSS).

it hit the iceberg. The key issue in such a situation should be to find the lifeboats and get as many people as possible into them. But in all societal sectors, we are continuing business as usual with no sense of urgency. The scientific community is acting as if we have all the time in the world to create the knowledge that is needed to overcome humanity's sustainability crisis. The private sector loves its addiction to growth and admires those who get rich beyond limits. The public sector continues to put local and national interests above global responsibility.

We also continue to define global principles and goals. The sustainable development principle attracts great intellectual capacity and political power to global summits, but its operationalization lags behind. The Millennium Development Goals (MDGs) have a great ethical value but reaching them is unlikely, particularly in Africa. Nevertheless, we go on to define Sustainable Developments Goals (SDGs) for the next decade,[7] but reaching those is not more likely than reaching the MDGs.

The science community also comes up with programs that have the potential to produce the knowledge that policy and decision makers would need to make progress towards MDGs and SDGs, but then these programs turn out not to be focused on reaching these goals, and they lack urgency. The most recent example is the Future Earth Initiative[8] conceived by an alliance of international research organizations, which has the goal "to develop the knowledge required for societies worldwide to face challenges posed by global environmental change and to identify and implement solutions and opportunities for a transition to global sustainability."

Achieving this goal could turn out to be crucial for humanity and our civilization. Given the rate of change we can expect if my metaphors of a run-away truck and of the Titanic have any similarity to our situation, the Future Earth Initiative may be the last initiative we can start to get the knowledge that could help us stop the truck, find the lifeboats, and make a transition to a more resilient and adapted post-modern civilization. Unfortunately, at all the science conferences I attend, which is a considerable number, the sense of urgency that I have is not the norm. ∧○

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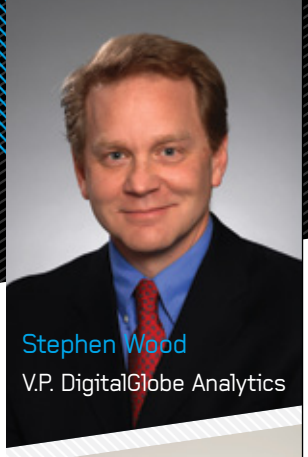

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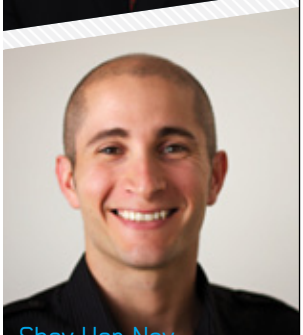

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Crowdsourcing Adds Capability

WITH ACQUISITION OF TOMNOD, DIGITALGLOBE DEFINES THE FUTURE OF ANALYTICS

MANY ASSUME THAT DIGITALGLOBE and other satellite providers have automated tools to search through the massive number of images taken each day by satellites circling the Earth, but that's not quite the case yet. It still comes down to the people and the analysts to identify what's most important and to provide context and insight.

DigitalGlobe has a long history of providing imagery for disasters and crises across the globe, ranging from war crimes in Sudan to the wildfire devastation in Colorado. The insights provided by combining imagery, geospatial analytics and all-source analysts can make a significant difference in evacuation planning, disaster response, recovery, and rebuilding in regions worldwide.

As a result of DigitalGlobe's recent combination with GeoEye, DigitalGlobe is equipped with a more advanced satellite collection system and some of the world's best geospatial production and analysis professionals. In fact, DigitalGlobe's constellation of five satellites can collect more than 1 billion square kilometers of imagery per year.

In order to add crowdsourcing analysis and deliver even more value to customers, DigitalGlobe acquired Tomnod, Inc., a crowdsourced intelligence pioneer. Tomnod has been at the forefront of innovation in the growing field of crowdsourcing of Earth observation imagery, combining their advanced algorithms with deep GIS and imagery knowledge. DigitalGlobe's acquisition of Tomnod has enabled the company to provide more timely insights and information of critical events worldwide.

THE POWER OF THE PEOPLE TURNS DATA INTO ANSWERS

Tomnod's crowdsourcing system helps DigitalGlobe achieve its vision of being the indispensable source of information about our changing planet by the year 2020. To effectively leverage the wisdom of the crowd, data reliability is key. Tomnod's advanced data reliability algorithm, CrowdRank, ensures that contributions from the crowd are properly filtered and weighted to maximize accuracy. By tracking crowd members' contributions over time, CrowdRank is able to rank the individual members of the crowd by tracking the areas of agreement and disagreement. This enables the system to

Publisher's Note:

Apogeo is excited to bring you a regular department on the fascinating and important subject of the Road to the Living Planet. We will cover progress that companies are making towards creating the reality of real-time access to all-source data on a digital "Living Planet." As the companies race towards this goal, we will share progress on many components needed, such as incorporating crowdsourcing, Big Data processing, the Cloud as an enabler, and more.

▲ FIGURE 1. Aftermath of Hurricane Sandy, Seaside Heights, N.J., Oct. 31, 2012. Image courtesy of DigitalGlobe.

identify inaccurate and even malicious contributions to truly leverage the wisdom of the crowd.

DigitalGlobe will continue offering Tomnod's rapid information capture and validation services directly to customers. In addition, information gained by the service will increasingly act as a key data source for DigitalGlobe's analytics team, enabling them to provide more accurate insight and analysis to customers faster.

DISASTER MANAGEMENT SUPPORT

Since the beginning, DigitalGlobe has excelled in meeting customers' needs for the quick delivery of satellite imagery, whether for military, environmental or humanitarian efforts. Satellite images provide an effective way to gauge the damage from disasters through comparisons of before-during-and-after images that geospatial analysts can use to provide answers

"Tomnod's advanced data reliability algorithm, CrowdRank, ensures that contributions from the crowd are properly filtered and weighted to maximize accuracy."

to the right people. In fact, DigitalGlobe's FirstLook service, which monitors disasters and crises worldwide, leverages its satellite constellation and ground infrastructure to collect and deliver up-to-date imagery of an event to customers in as little as four hours.

Before Hurricane Sandy hit the East Coast last October, DigitalGlobe satellites captured images of the affected areas, enabling the employment of change detection to narrow in on the most damaged areas. See *FIGURE 1*. And, even before Tomnod was part of DigitalGlobe, their crowd helped DigitalGlobe deliver insights to end users during this national disaster.

After the storm hit, DigitalGlobe's analysts quickly staged the before-and-after imagery within hours of collection so rescue workers and relief personnel could quickly understand the most affected areas and how to route first responders and relief supplies. As crowdsourcing comes of age, it reinforces what has always been true: the power of people makes the ultimate difference.

EXPANDED REMOTE GROUND TERMINALS FOR MORE REAL-TIME DATA

Over the last two years, DigitalGlobe also expanded the company's ability to download imagery quicker and cover more of the Earth's surface within a shorter window of time. The result is a much shorter period of time between data collection and product delivery by leveraging DigitalGlobe's worldwide network of polar and equatorial remote ground terminals (RGTs). DigitalGlobe's RGTs collect imagery downloaded from the company's satellites and send it to their facilities for processing.

All satellites have a limited amount of memory on board. As DigitalGlobe's satellites fly their orbits, the faster the satellites have access to a ground terminal, the faster they can download those images and have them sent back for processing. Clearing out the memory makes room for more images. At any one time, a majority of the Earth's land mass is within view of an antenna so images can rapidly be downloaded to an RGT and sent back to DigitalGlobe. This speed is particularly crucial during disasters.

Last summer during Colorado's devastating wildfires, DigitalGlobe was able to take images of the burn area and access a remote ground terminal to quickly download the images. This enabled analysts to identify the damaged neighborhoods and hotspots and get hard copy images into the hands of firefighters within a few hours.

DigitalGlobe has a constellation of five high-resolution satellites, a worldwide network of polar and equatorial remote ground terminals, and billions of square kilometers of archived, high-resolution imagery. These capabilities will now be supplemented with the power of Tomond's crowdsourced insight. By combining the speed, accuracy and capacity of DigitalGlobe's constellation with the crowd, DigitalGlobe will be able to deliver answers and insights more quickly than ever before.

DigitalGlobe is driven by its purpose, vision and values and plans to continue growing and bringing attention to world issues through satellite imagery and analysis, helping first responders on the ground after major world events. The new DigitalGlobe analytics team includes expert analysts from all over the globe who have experience in disaster management, predictive analytics and now crowdsourcing. DigitalGlobe strives to enable the world to harness the power of human insight, satellite imaging and geolocation technology to make a difference on a large scale. ∧♂

CAPTURING THE INDUSTRY DYNAMICS

INNOVATION & OUTREACH

SAVE THE DATE

6 – 9 May, 2014

Centre International De Conferences Geneva (CICG)
Geneva, Switzerland

www.geospatialworldforum.org

Space Systems for Sus

Sustainability through the

BY FILIPE DUARTE SANTOS, PHD / PROFESSOR OF PHYSICS AND ENVIRONM
FIRST VICE-CHAIRMAN OF THE UNITED NATIONS COMMITTEE ON THE PEACEFUL USES OF OU

The space environment is being used by more and more State and private sector entities for an increasingly diverse range of outer space activities. The long-term sustainability of these activities is currently in danger due to the proliferation of space debris, the growing probability of collisions, and the congestion of orbital positions and radio frequency spectra, particularly in the low-Earth orbit and geostationary orbit environments. However, space activities contribute decisively to the well-being of humanity and to sustainable development.

Sustainability is a relatively recent concept introduced in the 1980s and defined by the United Nations World Commission on the Environment and Development in 1987 as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition did not satisfy everyone, and other definitions arose. Gradually, it became clear that sustainable development is not a concept of a strictly scientific nature that can be defined without ambiguities; opinions differ on what precisely should count among the human needs for the application of the principle of intergenerational equity. These needs can be categorized into the social, economic, and environmental realms, but the relative importance of the different components is a matter of opinion.

Editor's Note:
See related story about water tracking on page 54.

Sustainable development is these days a meeting point for the debate about the state of the world and how to respond to the social, economic, environmental, and institutional challenges we are facing. We are still very far from achieving it but we can identify the main drivers of unsustainability, which can be organized into four leading groups. Space systems play a crucial role in addressing the problems raised by these four groups of drivers, which constitute the "square of unsustainability." See *FIGURE 1*.

The first group plays a prominent role among the others and includes the inequalities of development, poverty (especially extreme and severe poverty), hunger, and health and wellbeing deficiencies. The second group encompasses food insecurity, biodiversity loss, and scarcity of water and other natural resources.

The third, sustainability of energy systems, requires secure access to energy sources, affordable pricing and environmental compatibility. This last criterion is not satisfied by fossil fuels, which represent about 80% of the world primary energy sources, because their combustion leads to the emission of CO_2, a greenhouse gas.

Finally, the fourth driver is anthropogenic climate change, mainly due to CO_2 emissions from fossil fuel burning and to land use changes, especially deforestation. All four groups of drivers are strongly interconnected and interdependent. To reach some form of sustainable development, these issues must be addressed in ways that are both simultaneous and integrated. The magnitude and difficulty of this task reveal the perilous state the world is in.

INEQUALITIES OF DEVELOPMENT, POVERTY, HUNGER AND HEALTH

Since World War II, a remarkable acceleration in social and economic development worldwide has occurred, lifting hundreds of millions of people out of poverty and improving the quality of life of many more. However, poverty is still very significant and a major

impediment on the way to sustainable development.

According to World Bank statistics, about 50% of the world population live on less than $2.50 a day and about 80% on less than $10 a day. People living in poverty in the developing countries are focused on survival and therefore give a low priority to environmental problems. Furthermore, inequalities are increasing worldwide. More than 80% of the world's population live in countries where income differentials are widening.

Poverty is the main cause of hunger. According to the United Nations Food and Agriculture Organization (FAO), the number of hungry people has increased since 1995-97 and reached a peak of 1.02 billion in 2009. In 2010, it decreased to 925 million, which corresponds to 13.1% of the world population, or almost one in seven people. One of the main reasons for the recent trend in malnutrition is the increase in food prices since 2004, with major peaks in 2008 and 2011. See *FIGURE 2*.

Food prices are increasing for many reasons. One of them is climate change, which leads to more frequent weather and climate events such as droughts, floods and storms, and thus to crop failures. A further reason is the competition between energy and food through the cultivation of biofuel crops, which may take valuable farmland out of food production.

Also, the global population is growing too fast for agricultural production to keep up. In the developing countries, particularly in those with emerging economies, citizens are consuming greater quantities of higher quality food, which is a very welcome development but requires more water and energy, along with

tainable Development

Lens of the Unsustainable

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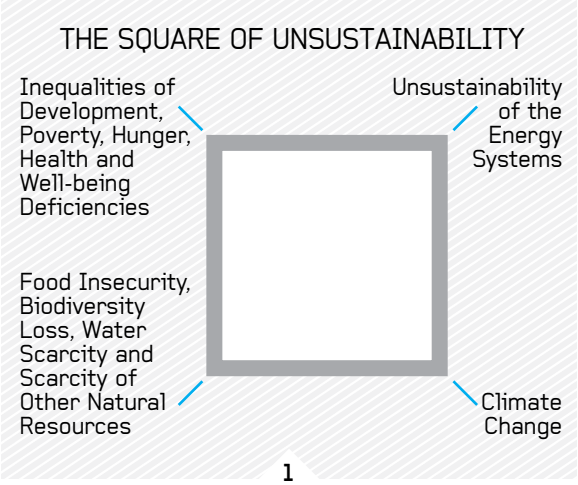
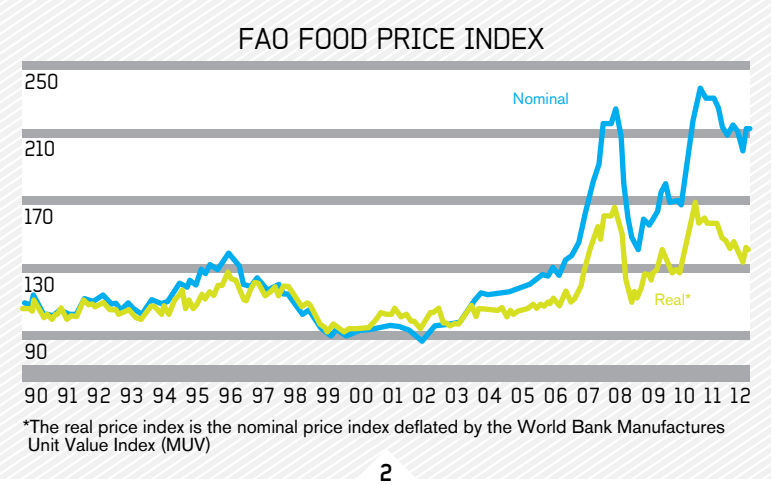
▼ **FIGURE 1.**
The Square of Unsustainability—a way to look at the issues that need to be addressed.



▼ **FIGURE 2.**
FAO Food Price Index showing spikes in prices since 2008.



good quality soils. The rising price of oil makes it more expensive to produce and ship food products. Finally, food prices are increasing because of decades of neglect of agriculture, especially in hunger-prone regions.

To increase the global food production in a sustainable way, an improved management of the world's agricultural resources is required. To achieve this goal, satellite imagery data must be used at different spatial, spectral and temporal resolutions. Space systems applications can be used for sustainable agricultural management and development, crop system analysis, integrated agricultural drought assessment and management, and assessment of land productivity and soil carbon dynamics.

A notable application of satellite data is the Famine Early Warning System Network, which was initially set up in Sub-Saharan Africa and now operates in other arid environments in developing countries. This system uses satellite images in conjunction with ground-based information to predict and mitigate famines.

According to the United Nations World Health Organization, water scarcity already affects every continent and 40% of the world population. The situation is getting worse because of population growth, urbanization and the increase in domestic and industrial water use. By 2025, nearly 2 billion people will be living in countries or regions with absolute water shortage, where water resources per person fall below the recommended level of 500 cubic metres per year, the amount of water a person needs for healthy and hygienic living.

Satellite imagery data are increasingly used for water resources monitoring and development plans. Satellite applications can measure rainfall, water movement and the height of water in rivers, lakes and wetlands. They can also serve to identify surface and underground water resources in drought-prone regions.

In the health sector, the inequalities among countries are growing at an alarming rate. Life expectancy, for instance, varies from less than 45 years in some sub-Saharan countries to more than 80 years in some OECD countries (Organization for Economic Cooperation and Development). The reasons for this profound disparity are well known: poverty, lack of adequate health infrastructures and medical services, lack of or inefficiency in the control of epidemics, and insufficient financing of pharmaceutical and medical research for the specific diseases of the tropical regions, where many of the developing countries are located. Satellites are essential tools in providing clinical health care at a distance through telemedicine. This technology improves the access to medical services in distant rural communities and also in emergency situations.

DEFORESTATION MEASUREMENT

Environmental monitoring using satellites has expanded widely in the past few years, and this trend is expected to continue. A very important example is the application of satellite imagery for forest monitoring and conservation. Deforestation began with the emergence of agriculture, which is responsible for a 20–25% reduction of the global forest area.

It is very difficult to make a precise assessment of the historical evolution of forested areas on a regional and global scale because different definitions and concepts of forestry have been used and because the quality of the data has a strong spatial and temporal variability. Currently, the situation has greatly improved through access to remotely sensed data, which provides a much more reliable form of monitoring.

According to FAO, around 13 million hectares of forest were converted to other uses or lost through

▶ **FIGURE 3.** Deforestation in the Amazon seen from satellite, showing the roads in the forest with a typical "fishbone" pattern, taken Sept. 20, 2006. Source: NASA.

natural causes each year between 2000 and 2010, in addition to 16 million hectares per year during the preceding decade. This results not only in biodiversity loss, but also contributes 12-15% to global warming by releasing CO_2 into the atmosphere and hampering further CO_2 storage.

Currently, the forests in the temperate zones of North America and Eurasia have stabilized or are increasing, while the tropical forests continue to decline. Using high-resolution satellite images, it has been possible to estimate that the average annual rate of tropical forest destruction between 2000 and 2005 was 5.4 million hectares and that about half of the deforested land is located in Brazil. See *FIGURE 3*.

About 60-70% of deforestation in the Amazon is the result of clearing for cattle pasture. Next is small-scale subsistence agriculture, construction of infrastructures, and large-scale commercial agriculture. By combining hundreds of images from satellite coverage with software analysis, experts can analyse patterns of deforestation down to a single tree and calculate the emissions resulting from removing trees that would otherwise sequester carbon dioxide.

The Millennium Ecosystem Assessment published in 2005 reports that the ecosystems have declined more rapidly and extensively over the past 50 years than at any other comparable time in human history. Left unchecked, this degradation jeopardizes the world's biodiversity and becomes a significant risk factor in business development and a threat to long-term economic sustainability. Satellite imagery is used to monitor and analyse habitat change and therefore to monitor ecosystems and biodiversity.

CLIMATE CHANGE

Climate change is one of the major environmental risks facing humanity in the 21st century. The scientific community has reached a strong consensus that anthropogenic emissions of greenhouse gases are intensifying the natural greenhouse effect in the atmosphere. These emissions are causing a climate change that will very likely intensify during the 21st century. The signs that this climate change is happening are becoming ever more obvious and unequivocal. According to the Intergovernmental Panel on Climate Change (IPCC), the global average surface temperature (land and ocean) has increased by 0.8° C since pre-industrial times and by 1.0° C over land alone. In the Arctic, the average surface temperature increase has been higher, about twice the global value.

▼ FIGURE 4.
Hurricane Sandy, October 28, 2012. Source: NASA.

All 10 years with the highest average surface temperature from 1850 up to 2012 have ocurred since 1998. While 2012 was the ninth warmest year, 2005 and 2010 ranked as the hottest years on record. The ice sheets are losing mass, glaciers are shrinking globally, sea ice cover is reducing in the Arctic, and snow cover is decreasing and permafrost is thawing in the Northern Hemisphere. Ice is being lost from many of the components of the cryosphere, although there are significant regional differences in the rates of loss.

The temperature of the upper ocean layer down to 75 m is increasing more than 0.1° C per decade. More than 90% of the extra energy stored by the Earth between 1971 and 2010, as a consequence of the increased greenhouse effect, has gone into ocean warming. As a result of thermal dilatation, melting of mountain glaciers and, to a lesser extent, melting of the polar ice sheets, global average sea level is rising. It increased between 14 and 20 cm in the 20th century and is presently increasing at an annual rate of 2.7 to 3.7 mm. Climate models indicate that mean sea level will continue to rise at increasing annual rates, reaching a value on the order of 0.5 to 1.4 m, relative to pre-industrial times, at the end of the 21st century.

EXTREME WEATHER INCREASE

In addition to the temperature changes and the rising sea level, another very important aspect of anthropogenic climate change, which has a strong potential impact in many human activities and socio-economic sectors, is the increase in the frequency and intensity of extreme weather and climate events. There are clear indications that the percentage of very strong tropical storms, such as the recent Hurricane Sandy in the North Atlantic, is increasing. See *FIGURE 4* on page 33.

▶ **FIGURE 5.** Satellite map of North America. Source: NASA.

Earth observation from space over the past 50 years has fundamentally changed our understanding and knowledge of the Earth system. See *FIGURE 5*. With increasingly sophisticated space systems, it is now possible to obtain quantitative measurements of temperatures in the atmosphere, concentrations of atmospheric gases, precipitation and wind speed, elevations of land and water, water movement, types of soils, and vegetation cover. In addition, satellite observations yield continually updated knowledge of the state of the atmosphere, helping meteorologists to devise models that project the weather into the future with much improved accuracy compared to pre-satellite forecasts. Seven-day forecasts have more than doubled in accuracy over the past three decades, particularly in the Southern Hemisphere.

Satellites have been used to monitor the stratospheric ozone layer, which blocks damaging ultraviolet light from reaching the Earth's surface, and to monitor atmospheric aerosol loading. Furthermore, they have contributed decisively to improvements in our understanding of the climate system and of climate change, through monitoring of the atmosphere, sea and land surface temperatures, ice sheet floes, Arctic sea ice extension, the El Niño-Southern Oscillation, and Earth's carbon cycle. Recently, an ensemble of satellite altimetry, interferometry, and gravimetry datasets has been used to conclude that, since 1992, melting of the polar ice sheets has contributed, on average, 0.59 mm to the annual rate of global sea level rise.

Extreme precipitation and floods are very likely to become more frequent because of climate change. Floods are just one example of various types of disasters where satellites are very useful for humanitarian relief, rapidly mapping and assessing local emergency situations and reconstruction activities. Space systems are extensively used these days in the management of disasters related to geophysical, meteorological, hydrological and climatic events. The uses of satellites in disaster management are becoming more integral to reducing reaction time and to providing accurate information for rescue and disaster control operations. Satellites are very useful in disasters for communications, remote sensing and mapping. Meteorological and storm warning satellite technology can also help in predicting water-related disasters and in setting up precautionary activities.

Many more examples could be given of the importance of space systems for sustainable development. Satellites are currently indispensable to our way of life. One day without civilian satellites would bring chaos to the global human society. Some of the consequences would be the loss of GPS, cell phones, internet access, all traffic control, and access to financial markets, as well as a severe impairment of most weather forecast services. For longer periods of time, the loss of satellites would bring the collapse of civilization as we know it. It is therefore of the utmost importance to guarantee the long-term sustainability of outer space activities. ∧♂

Water scarcity already affects every continent and 40% of the world population... By 2025, nearly 2 billion people will be living in countries or regions with absolute water shortage, where water resources per person fall below the recommended level of 500 cubic metres per year, the amount of water a person needs for healthy and hygienic living.

5

Mapping Disasters

Changing the Focus

BY DR. DOUGLAS ZIMMERMAN, PRESIDENT AND CEO
VISIONLINK, INC. / BOULDER, COLO. / WWW.VISIONLINK.ORG

Geospatial solutions need a shift in focus to reach the next level of acceptance and impact for disaster relief. What has been applied to incidents in the immediate aftermath of disasters can be strengthened. The solution brings new partners to the table, extends the timeline for use, focuses less on display and more on the listener, and attends to the private and public understanding of location-specific situational awareness tools, and how to use them appropriately.

Interestingly, the path to success is defined by what is missing: the partners, the later stages of disaster, the connections with those who can truly respond, and more informed use by both expert and public alike.

RE-DEFINING THE PARTNERS

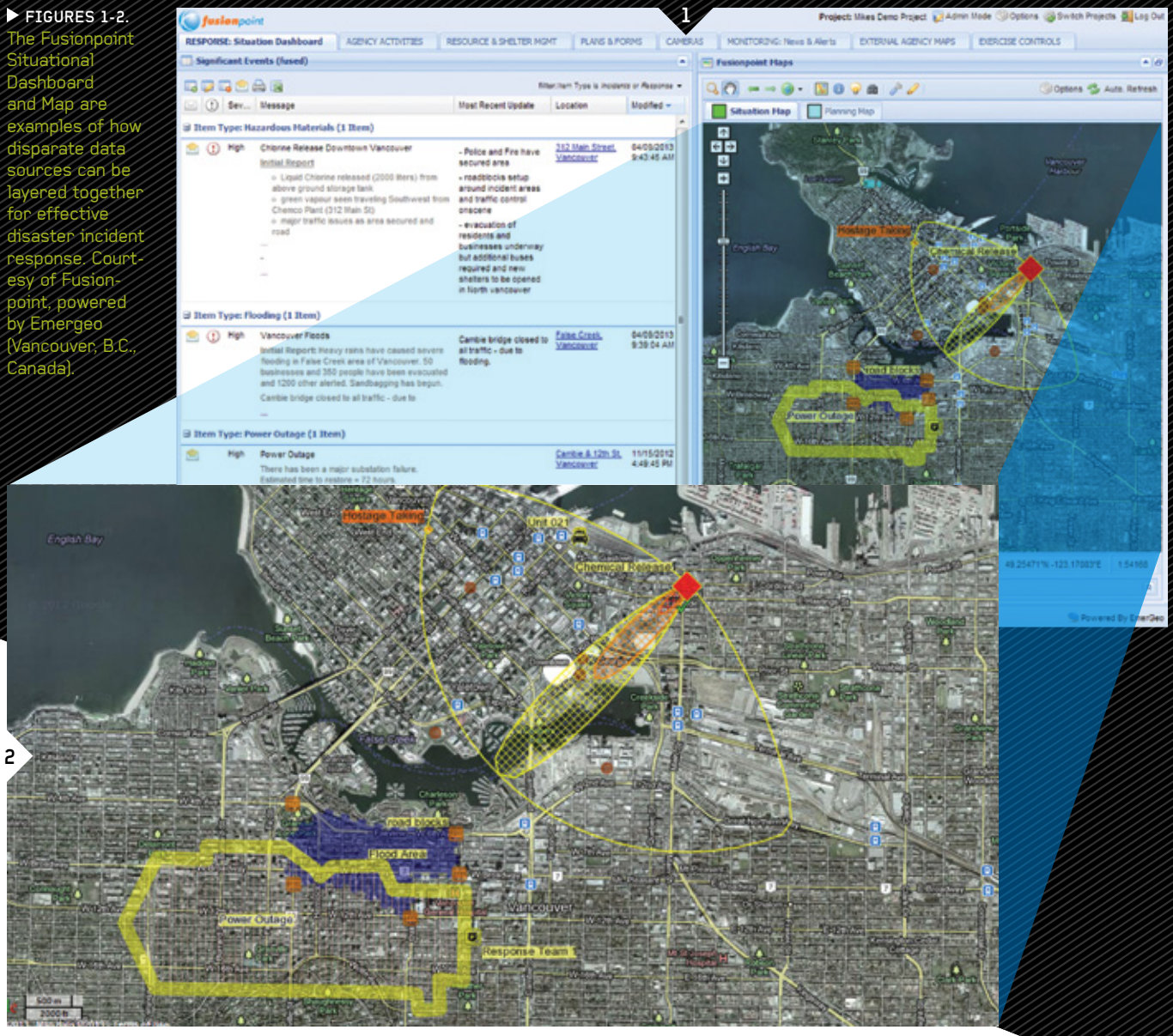
Let's look at the partners who typically engage in disaster planning. Well engaged are the professional emergency management officials, various government agencies responsible for response, and a range of sophisticated planners, many with powerful scenario modeling tools. In addition, technical and software vendors contract and contribute their expertise in what can be measured, displayed, and analyzed.

Who is missing at this table? Missing are those who spontaneously organize, the charities, faith-based groups, the voluntary agencies, the other citizen groups who collectively bring most of the volunteer hours, and a great deal of the long-term recovery capacity. These organizations are also the least likely to have the resources to participate in planning exercises. They are the same entities, however, for which geospatial tools can change the calculus of their engagement.

The same agencies that rarely have sufficient discretionary resources to engage in disaster or emergency planning are the same entities that know they need to do a better job analyzing the gaps between the location of their resources and the location of their clients. Moreover, these same organizations work every day to help those in need by managing a tremendous inventory of community-based resources. Many of these are the same resources deployed for long-term disaster recovery. By helping to map day-to-day resources for these less engaged organizations, emergency and disaster professionals gain access to critical information about community assets that can be used in response and long-term recovery.

By organizing information for NGOs and others who help the needy in communities every day, those with geospatial expertise change the calculus. With the promise of better analytics for everyday operations, these NGOs can justify their involvement, will be more willing to share data, and will almost incidentally contribute their knowledge of local assets and resources for the purposes of emergency planning.

The approach? Consider stepping out of the emergency management silo and simply approaching the



FIGURES 1-2. The Fusionpoint Situational Dashboard and Map are examples of how disparate data sources can be layered together for effective disaster incident response. Courtesy of Fusionpoint, powered by Emergeo (Vancouver, B.C., Canada).

NGOs with the offer to use disaster planning tools to help them analyze the proximity of their resources to their clients. Build on that simple offer, and as the work progresses, then, and only then, take the step to connect the dots between everyday operations and emergency response. Working together you will increase the resiliency of every partner at the table, but it starts with attending to everyday needs, not the needs of the occasional crisis.

RE-DEFINING THE FOCUS

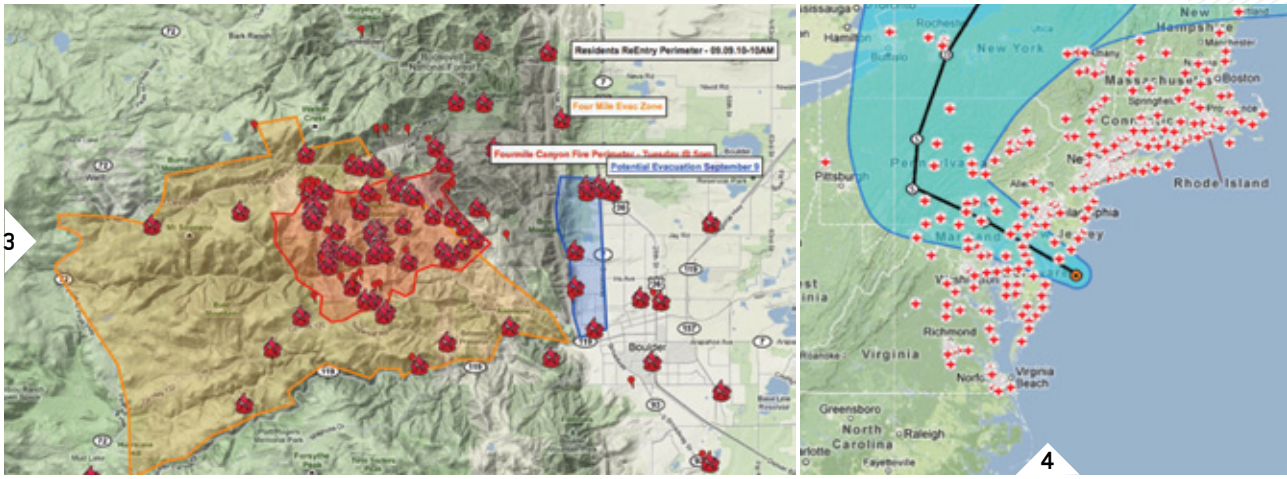
As more partners are engaged, re-defining the targeted phase of disaster recovery is next. Typically, disaster analytics are focused on the period immediately before a catastrophe (as with, for example, water-level monitors), immediately after a disaster (as with impact or evacuation boundaries, and mobile kitchen and shelter locations), or on the metrics of need (as in block-by-block surveys of damage.)

Consider, however, focusing the power of situational analysis on the later stages of disaster recovery. Admittedly, this focus is not as immediate, nor does it satisfy the need for real-time insight as a large-scale disaster

> "Geospatial systems are not able—on their own—to filter for quality data as the wise expert does intuitively."

unfolds. Let's consider the curve of expenditures after a disaster. Immediately after a flood, hurricane, or forest fire, for example, substantial resources are deployed to feed and shelter survivors, to conduct search and rescue, and to assess the damage. Once this stage winds down, however, then the rebuilding begins and the sums of expended resources increase substantially.

Said another way, when the news cycle dies down about any disaster, recovery has barely begun. The power of geospatial tools, by the visual nature of the medium, can help extend focus and attention on the less dramatic but very real long-term work that lies ahead. Months after the impact of Hurricane Sandy, thousands of people still had no home to return to and no affordable permanent housing option. Information about the clustering of these homes, the status of recovery, and information about specific needs could all be easily communicated to help coordinate assistance and engage donors.



▶ FIGURE 3. During the surge of large-scale fires in Colorado during 2010, joint operation situational maps successfully combined social media (vetted and non-vetted), public data feeds, and professional disaster data for a more comprehensive situational map. This particular view focused on the fires in the Boulder, Colorado area where burnt structures were reported by the public via social media and verified by disaster responders.

WHO IS LISTENING?

Depending on the locale, some situational awareness tools are still being used in pilot or test mode. Some systems are still proving themselves, and in that mode, beginning to use the tools is often more important than using them well, or as fully developed as will be eventually possible. As these technologies mature, however, professionals and the public alike need to ask whether anyone is listening.

The key question is whether or not the solution is linked to any entity who is listening, and also able to do something with the information.

The most elegant display, the most articulate laying of data is all for naught if there is no organizational capacity on the other side to do something with the information. In fact, false expectations can be raised among those who can "see" all the data without understanding the logistics of response and recovery. Now that geospatial solutions are well proven, the efficacy of their use will be determined less by the pace of advances (which are already ahead of most audiences) and more by the linkages between the data and the decision-makers (particularly at the middle management layer) who need to act on the data.

Many disasters have received careful and well meaning attention from numbers of volunteers who have stood up tremendously useful mapping solutions, often within hours or days of the incident. The efficacy of that work will be determined, however, not by the depth and dimension of the data, but by the degree of separation between the new mapping solution and the previously established entities that are formally chartered to respond to disasters. Yes, geospatial solutions needed to prove themselves first. Yes, there will be even more amazing advances in the technology. Now, the barrier to efficacy is not, however, the technology. It is the link between data, display and decision maker. Those are the dots that need attention now.

A NEW KIND OF EXPERTISE

Ask a gathering of disaster professionals about their own leaders, or their own expertise, and most will mention a highly respected senior member of their group who "has forgotten more about disaster relief that most of us will ever know." These senior members are often said to have a near-perfect gut level understanding for the ebb and flow of disaster response. This is an expertise borne of years and years

of field-level experience, a vast network of trusted relationships, and a gritty sense of the real world.

Geospatial solutions can interrupt the decision making of such wise elders. Why? Because many of those with highly trusted expertise are not those willing or able to accept the insights of new real-time situational analysis systems. Or more specifically, geospatial systems are not able—on their own—to filter for quality data as the wise expert does intuitively.

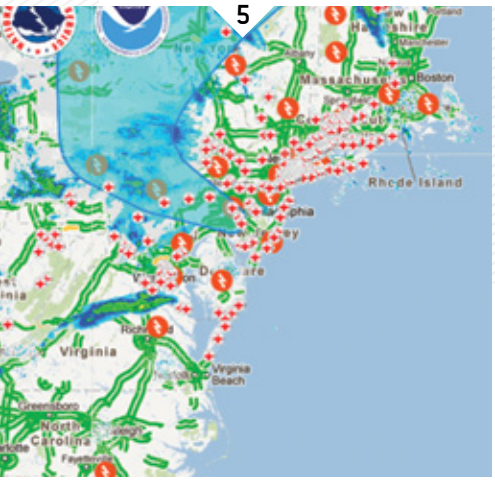
Conversely, geospatial tools can display so much information, quickly and elegantly, that less experienced decision makers may weigh the wrong data too heavily, or may not rely sufficiently on reports from the field, or may treat all data as equally valid. The result can be poor decision making at the worst time.

relief customers such as the Red Cross need to review Twitter feeds for distress calls, we need to be capturing every single relevant tweet, not a sample of those tweets.

The challenge is then three-fold. Experienced disaster relief professionals need to add to their network of trusted relationships a nuanced understanding of data sources, reliability, quantity and quality. Geospatial experts can focus less on the pace of improvement, and more on connecting the dots between data systems and authoritative relief agencies that are resourced well enough to respond at scale.

PARTNERS, FOCUS, NEW EXPERTISE

The leading edge of geospatial technology is exciting and inspiring: true.



> "Now, the barrier to efficacy is not the technology. It is the link between data, display and decision maker. Those are the dots that need attention now."

◀ **FIGURES 4-5.** During the recent impact of Hurricane Sandy, situational maps for both public and professional consumption leveraged data sources for weather, regional power grids, the National Shelter System, and social media to provide a more comprehensive view for disaster responders. Additionally, professional responders can then plot locations and current needs of disaster victims and currently available resources to facilitate better allocation of support resources.

The solution is resource intensive. Tabletop and field exercises become more important as the task is not only to work the problem towards a solution, but to work the problem with entirely new sets of data flows never before available. This is the story of all new technologies and adoption curves. With disasters, however, quantity and quality of data are nearly always inversely related.

The public also needs to become more aware of how different sources of data are interpreted by their local officials. As an example, when the American Red Cross surveyed more than 1,000 adults about the use of various social media sites in 2010, 35% responded that they would post a request for emergency assistance on the organization's Facebook page, and 28% said that they would send a Twitter message directly to the relief organization.

In VisionLink's work, we use a social media feed from GNIP (Boulder, Colo.), a worldwide leader in social media data aggregation. We do so because if our disaster

The efficacy of its application will be determined going forward however, by much more mundane needs. Let's find ways to engage the community agencies and the various NGOs that service the community day-to-day. Focus on the long-term, multi-year needs of recovery, not only the flash of incident management. Make sure that the organizations that control the resources of recovery are actually linked to, and "listening" to these amazing tools.

Finally, take on the challenges of adding geospatial solutions to the trusted toolkit of the experienced professional, of the limits of real-time data for those new to the profession, and of public awareness about appropriate and inappropriate channels of communication.

Geospatial platforms are not simply ways to inform professionals; they have an inherent capacity to inform and educate a wide range of stakeholders. It is time to move beyond prototypes and pilots, becoming the tool of choice as communities rebuild after disasters. ∧○

GIS + RS = A New World!

Integration Becomes a Reality

BY MATTEO LUCCIO, CONTRIBUTOR / PALE BLUE DOT, LLC
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THE SCIENCES, TECHNOLOGIES, AND PRACTICES OF REMOTE SENSING AND OF geographic information systems (GIS) arose separately, developed in parallel, intersected, and are now inextricably linked. Nearly all the features in most GIS are collected by means of satellite imagery or aerial photogrammetry, and GIS is the application where this imagery is most commonly visualized. "All the foundation elements of GIS come from remote sensing: roads, buildings, water and cultural features, topography, terrain, soils, slopes, geology, and many more," points out Lawrie Jordan, Director of Imagery at Esri.

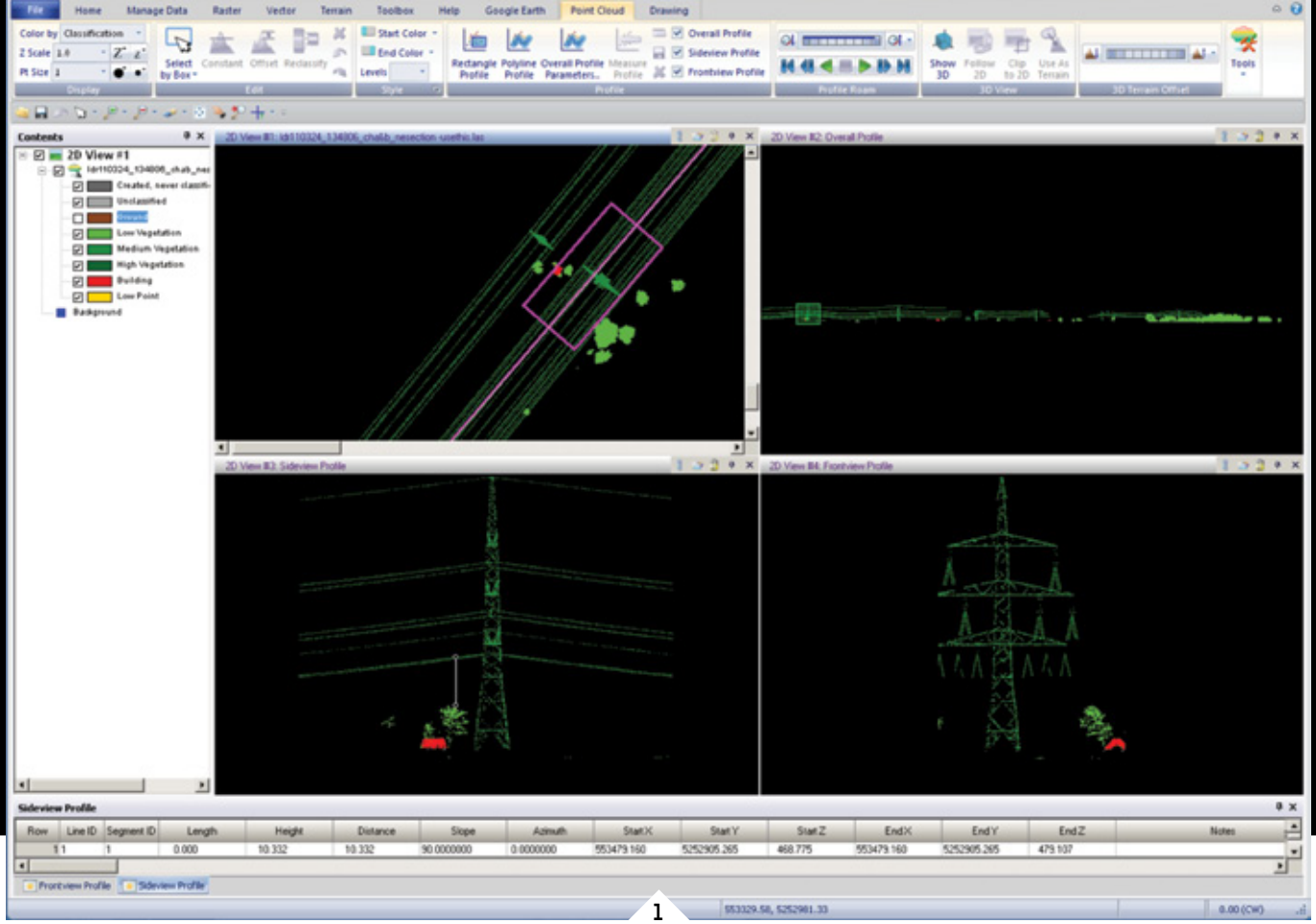
MERGING TWO APPROACHES

It was not always this way. In the 1970s, 1980s, and early 1990s, remote sensing and image processing, on the one hand, and GIS on the other, were separate worlds—each with its own culture and software. The former stored data in a raster format and used multispectral classification; the latter stored data in a vector format and used topology. Software vendors specialized in one or the other—even though their customers were acquiring and using both types of data. Until recently, in a GIS context, imagery was thought of only as a background or a basemap to the information that was being analyzed.

Over the last decade, however, remote sensing and GIS have become increasingly integrated. "Now people are seeing imagery as a source of a lot of GIS information," says Jennifer Stefanacci, Director of Product Management at Exelis. "So, the analysis workflows that our users are doing incorporate both analysis of the imagery and analysis of their GIS data." While GIS gives you the information about 'where,' through information extraction routines, remote sensing gives you the information about 'what,' explains Mladen Stojic, V.P. of Geospatial at Intergraph, "By merging the

Sensors & Systems

Editor's Note:
This article was previously published in our partner publication, *Sensors & Systems*: http://bit.ly/15tKPEU



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Mladen Stojic
INTERGRAPH

two, we now have the opportunity to do modeling with raster data, vector data, and, on top of that, terrain data."

Today, GIS is the most practical and efficient platform to combine remote sensing with other layers of information. "People do not acquire and process imagery just to make a pretty picture out of it," says Jordan. "They want to combine it with other spatial information to solve problems and create meaningful results."

WORKFLOWS

In the traditional linear image processing workflow, which has been standard for more than 30 years, a technician classifies, rectifies, and mosaics each image, creating many intermediate files. This process is very labor-intensive and requires a lot of storage space. By contrast, the new technology processes the imagery within the framework of a GIS in near real-time on demand, Jordan points out. "The architecture for doing this uses a very intelligent geodatabase structure called a mosaic dataset, so you can define the process chain of what happens to the image dynamically, and pull the image through it. You can do orthorectification, color balancing, pan-sharpening, and mosaicing, on datasets of virtually unlimited sizes, all dynamically, on the fly. This is truly a game changer."

▲ FIGURE 1. Classified LiDAR dataset of a powerline corridor with the ground class turned off, used to measure encroaching vegetation. The planimetric view and three profile views are visible. Image courtesy of Intergraph.

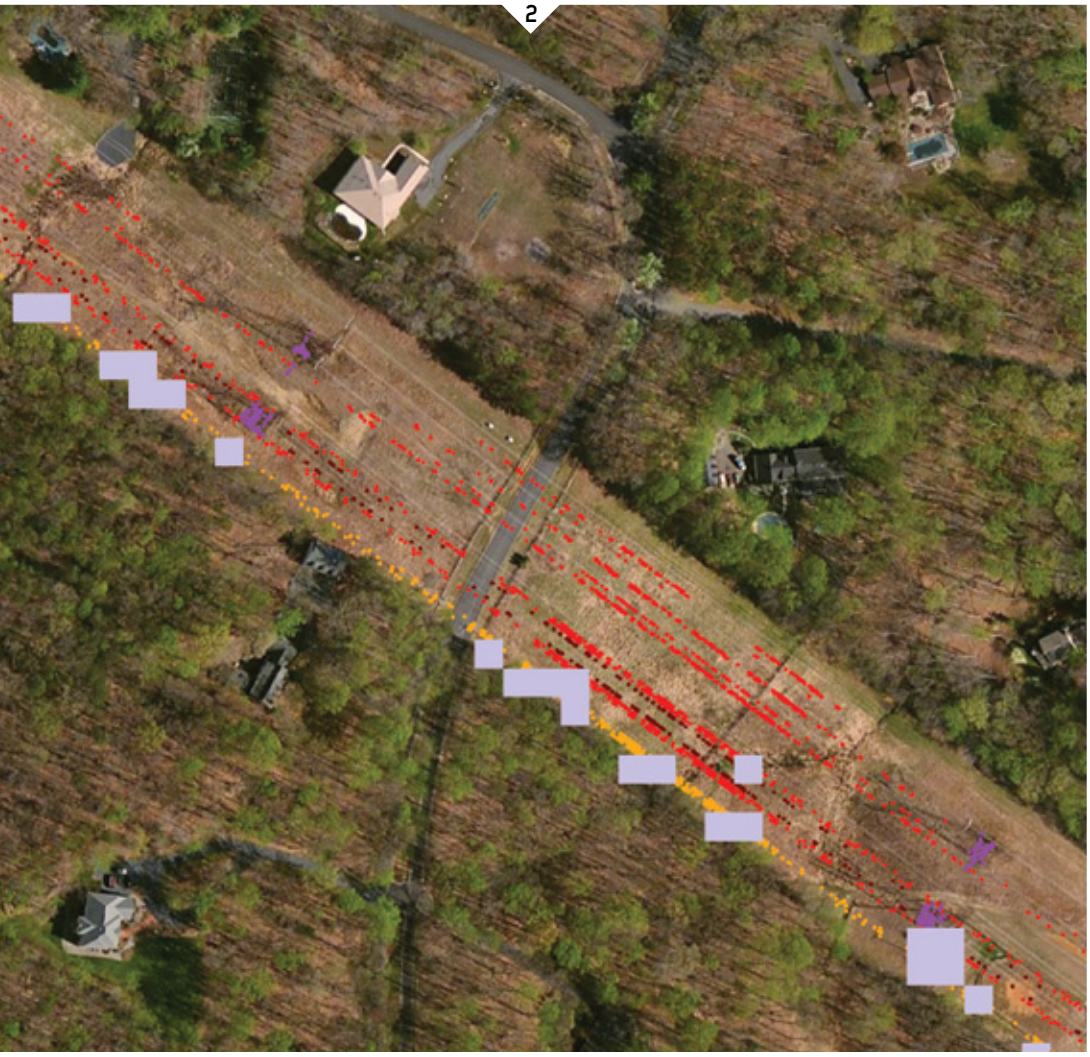
Exelis has been working with Esri for about four years on developing workflows that allow users to use the two companies' products in a combined fashion. "We realize that users have access to a variety of data and the better they can leverage all of their data, the better decisions they can make," says Stefanacci. "So, we've built workflows that allow users to move smoothly between ENVI and ArcGIS and make it easy to do their analyses without having to think about using many different software products."

For example, to find out the area of rooftops in a subdivision, a land assessor can use Fx from the ENVI Toolbox in ArcMap to identify the rooftops in his image, then output to a shapefile and use ArcMap spatial analysis tools to analyze which rooftop areas have changed since the last assessment. In another scenario, a city planner asks his GIS specialist which parks in their city have been added in the last four

> The point of convergence has been the modernization of the map. That's not because of Esri or Intergraph, but because companies like Google and Microsoft have introduced a new philosophy about the map and the layers of information inside it.
>
> – *Mladen Stojic, Intergraph*

years. Unfortunately, the records have not been kept and this information is not readily available; however, the city does have imagery available. Since the timeframe is too short for the GIS specialist to visit each park to update her maps, she uses imagery to identify all of the park land. She performs a "classification without training data" from the ENVI toolbox on the earlier image and a current one, and then runs a change detection to determine which of the park areas have changed. Finally, she uses this data to update the city's GIS database.

LiDAR data files present special challenges because they are huge. To use them in Esri products, users must first chop them up, says Stojic. "So, it's hard for people to find and effectively manage the raw data, which is most valuable." Intergraph's 2013 release, he says, solves that problem in three ways. First, it enables users who cannot afford a LiDAR sensor to create very accurate and dense point cloud datasets from stereo imagery. Second, it enables them to harvest the metadata and then use it to catalog, manage, find, and download the data they need. Third, it allows them to natively support the data from a visualization and an exploitation perspective, "meaning that you can take an LAS file and not have to convert it into a different dataset and create redundant data on disk, in order to use it." See *FIGURE 1* on page 41.



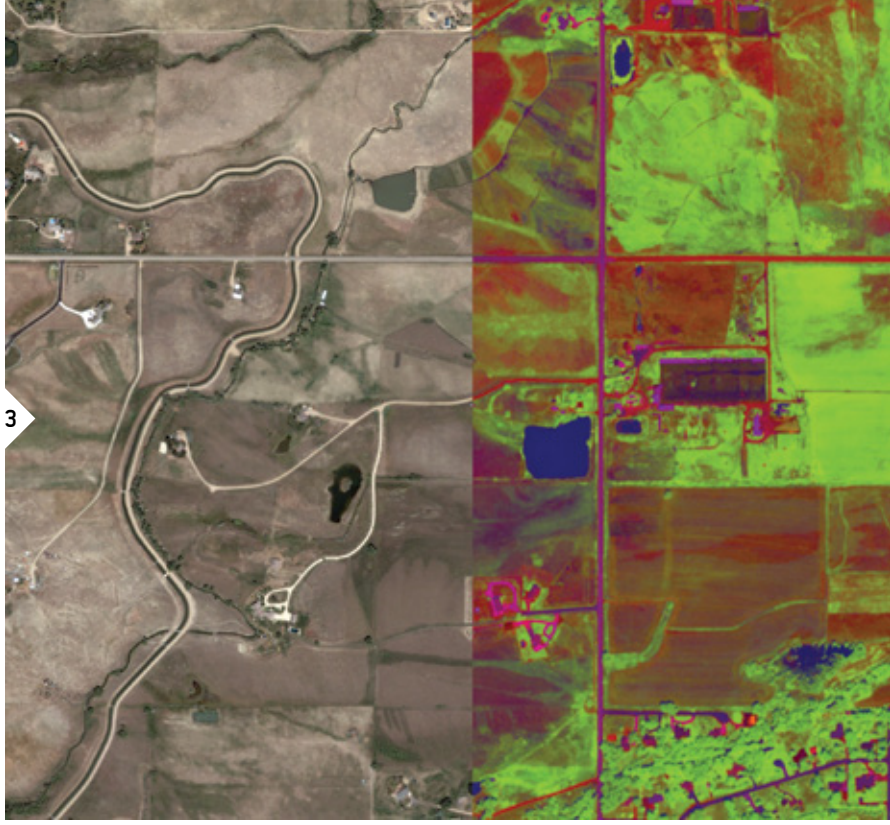
INTEGRATION

The variety and amount of remotely sensed data available to users has increased dramatically in recent years—and will continue to increase, as LiDAR sensors come down in price, new satellites

▲ **FIGURE 2.**
Analyzing airborne LiDAR to identify work order areas for inspection along utility corridors. Image courtesy of Esri.

are launched, and UAVs become ubiquitous. Organizations often have LiDAR, SAR, multispectral, hyperspectral, and panchromatic data—each of which has its unique benefits—and can now analyze them using a single package and integrate them seamlessly into GIS. According to Jordan, imagery is fully integrated throughout all the ArcGIS products—desktop, server, mobile, and in the cloud—and they are very rapidly improving their capability to support imagery. See *FIGURES 2-4*.

"By bringing together Intergraph and Leica Geosystems, Hexagon has specifically targeted the integration of surveying, photogrammetry, cartography, GIS, and remote sensing, so that the 'Smart Map,' as we like to call it, really becomes the point of convergence," says Stojic. "We hope to break down the historical silos that have been built up because of proprietary, closed systems." Intergraph's 2013 release, he claims, fulfills this "dream and vision." See *FIGURES 5-7* on page 44.



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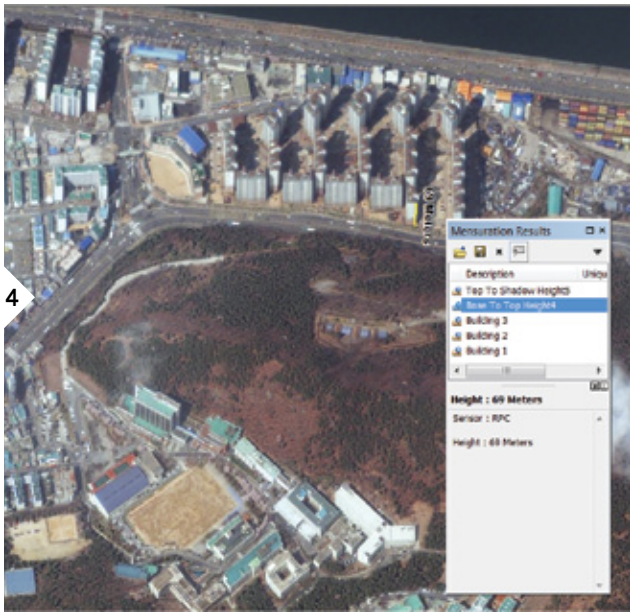
▲ FIGURE 3. Using image analysis algorithms to analyze and map wetness and vegetation vigor in imagery. Image courtesy of Esri.

Jennifer Stefanacci
EXELIS

THE CLOUD

In geospatial technologies, as in many other fields, the trend is to move beyond traditional file-based architectures toward cloud-based services. At the same time, there is increasingly a need for easy access to large volumes of imagery and analysis tools. "This has resulted in demand for online dynamic services rather than just static capabilities," says Jordan. "These are being offered as cloud-based services through a new business model which is based on subscriptions and credits. The latest version of ArcGIS Online contains a significant amount of global high-resolution imagery and this will soon be accompanied by a new series of premium services." The move toward cloud-based solutions will also further accelerate the fusion of geospatial technologies and data layers.

▼ FIGURE 4. Measuring the height of features in satellite imagery. Image courtesy of Esri.



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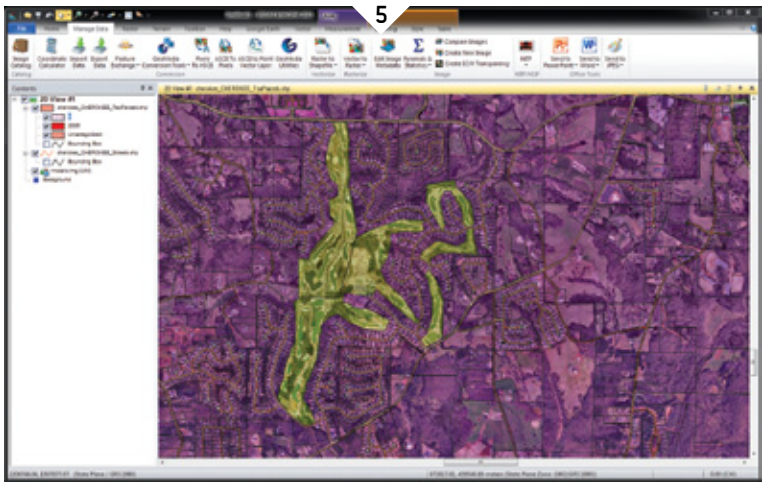
3D

Ten years ago, few software programs were capable of generating 3D visualizations. Now, thanks in part to Google Earth and Bing Maps, 3D has become commoditized and expected. "We introduced our first 3D product in 1996," Stojic recalls. "Since then, graphics cards have become more powerful and more 3D-aware and their price point has dramatically decreased, driving up adoption. You now have a culture that is 3D-aware. Most people won't even look at your product if you don't do 3D right out of the box."

To enhance its 3D capabilities, Esri recently acquired Procedural, the maker of a product called CityEngine, designed to create 3D cities. "The future trend for feature extraction is really about extracting 3D environments," says Jordan. "Esri recently acquired a very large collection of current, high-resolution DigitalGlobe imagery for the entire planet and I believe that's going to drive a lot of these new 3D visualizations." While Esri is working on visualizing 3D point clouds, Exelis' tools focus on extracting infor-



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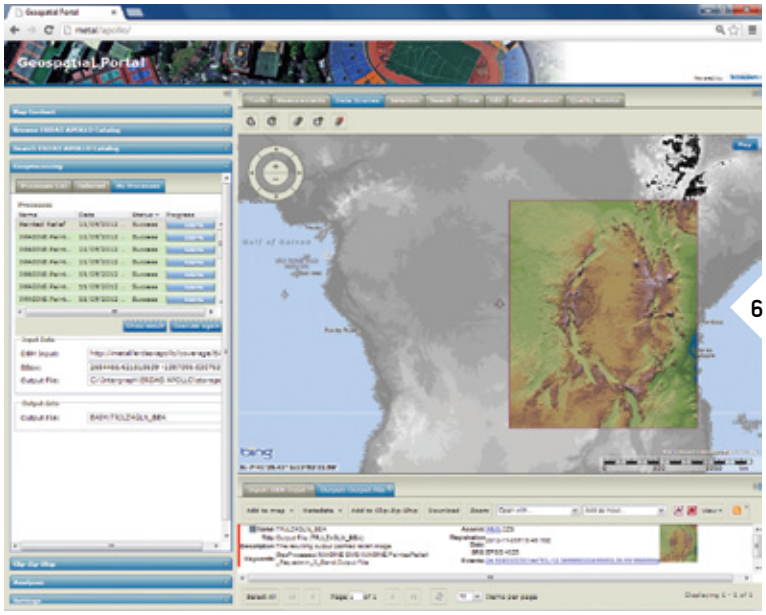

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mation out of the point cloud and turning it into data that users can incorporate into their GIS databases, says Stefanacci.

AUTOMATED FEATURE EXTRACTION

The Holy Grail at the intersection of remote sensing and GIS is rapid, efficient, and accurate automated feature extraction. It is an iterative process in which a specialist repeatedly tweaks different parameters to create templates, which are then used by others to update or extract features.

In its 2013 release, Intergraph has introduced a new modeling environment that expedites this process, says Stojic. "You will start to see more of our feature extraction and change detection tools migrate over into this dynamic modeling environment so that we shorten that lifecycle and streamline the process required to get the best information layer out of this automated change detection technology."

▲ FIGURE 5. The 2013 release of ERDAS IMAGINE provides greater raster and vector integration. Image courtesy of Intergraph.

▲ FIGURE 6. In conjunction with the Geospatial Portal, ERDAS APOLLO offers on-the-fly geoprocessing that enables users to execute spatial models from a Web client. Image courtesy of Intergraph.

Exelis also has a strong tradition in this area. Its ENVI LiDAR product has automated methods to extract buildings, trees, powerlines, and power poles directly from the 3D point cloud, says Stefanacci. "We are looking at adding additional feature types in our upcoming releases." See *FIGURE 8*.

UAVS AND MICROSATELLITES

Lawrie Jordan
ESRI

The amount of data collected by UAVs and microsatellites is about to explode. "It's the digital fire hose in the sky and the best thing that's ever happened for remote sensing," says Jordan. "Clients around the world, such as major oil companies and defense and intelligence organizations, are using ArcGIS to handle tens of millions of high resolution images dynamically. ArcGIS is highly scalable and was designed that way from the beginning in anticipation of this essentially global, persistent surveillance. I believe that, very soon, we are going to be mapping, measuring, and monitoring every square meter of the surface of the Earth in near real-time. There will be several hundred orbiting, on-station imaging satellites."

Hexagon is also playing in that space. For example, two years ago it released software to extract features from motion video. "We are looking at geo-referencing software and the development of the aerial triangulation required to stitch together multiple frames over time in order to get a highly accurate data product out of that data source," says Stojic.

THE MAP OF THE FUTURE

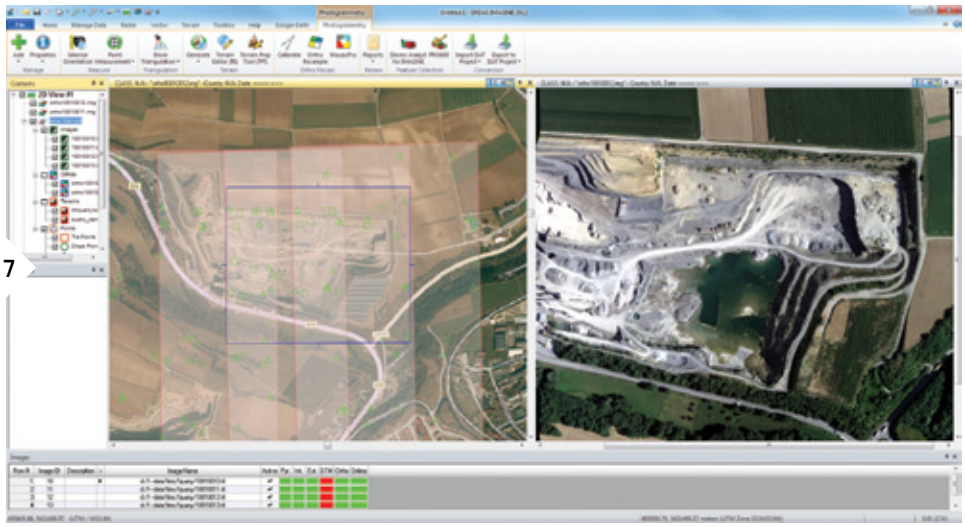
What brought remote sensing and GIS together? "The point of convergence," says Stojic, "has been the modernization of the map—by which I mean Google Maps, Bing Maps, location-aware maps. That's where we've seen the two philosophies come together to form one approach to mapping. That's not because of Esri or Intergraph, but because companies like Google and Microsoft have introduced a new philosophy about the map and the layers of information inside it. Other professional vendors are continuing to support that fusion through the synthesis of raster, vector, and point cloud data in modeling applications, in workflows, and so forth."

How are these developments in remote sensing

> The map of the future is not really a map at all, but rather an intelligent 3D image... What I see happening is something I like to think of as the 'Living Planet'—global persistent surveillance, where all of these sources are made available dynamically. GIS is the ideal environment to bring all this together. It's the most exciting time in the more than 40 years that I've been involved with this.
>
> *– Lawrie Jordan, Esri*

and GIS going to affect the end product for most consumers of geospatial information—the map? "The map of the future is not really a map at all, but rather an intelligent 3D image," says Jordan. "It is going to be photo-realistic, and you will be able to fly through it, navigate, interrogate, analyze, visualize, and then collaborate and share it with others. It will all be cloud-based and imagery is going to drive that. What I see happening is something I like to think of as the 'Living Planet'—global persistent surveillance, where all of these sources are made available dynamically. GIS is the ideal environment to bring all this together. It's the most exciting time in the more than 40 years that I've been involved with this."

The integration of remotely sensed data and GIS is at the center of a larger trend toward the fusion of different kinds of geospatial data and technologies that also includes video, sensor networks, and GPS-based tracking of mobile assets. At each step in this integration, the new capabilities progress rapidly from advanced to standard features. For scientific, governmental, commercial, and consumer applications, the line between reality and virtual reality is blurring, which is very exciting indeed. ∧○



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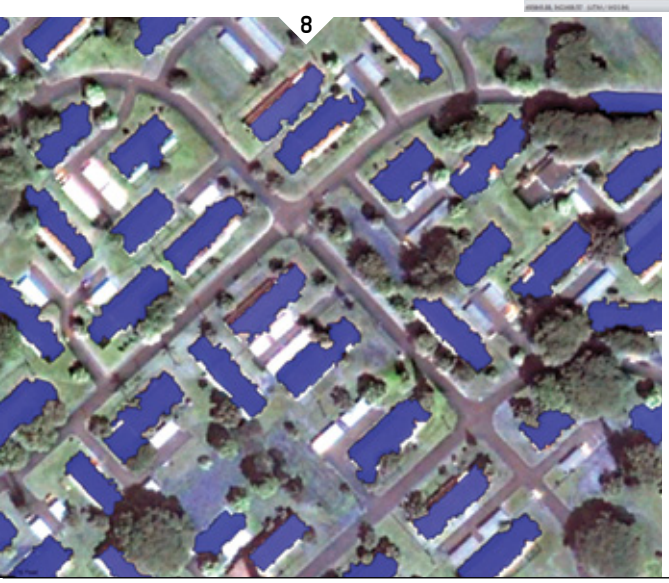

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▲ **FIGURE 7.**
The LPS ribbon interface provides access to remote sensing functionality. Image courtesy of Intergraph.

◀ **FIGURE 8.**
The ENVI Feature Extraction Module (ENVI Fx) provides tools to read, explore, prepare, analyze, and share information extracted from all types of imagery, such as the rooftops in this image. Image courtesy of Exelis.

Astrium

Impressive Constellation & Faster, Easier Data Access

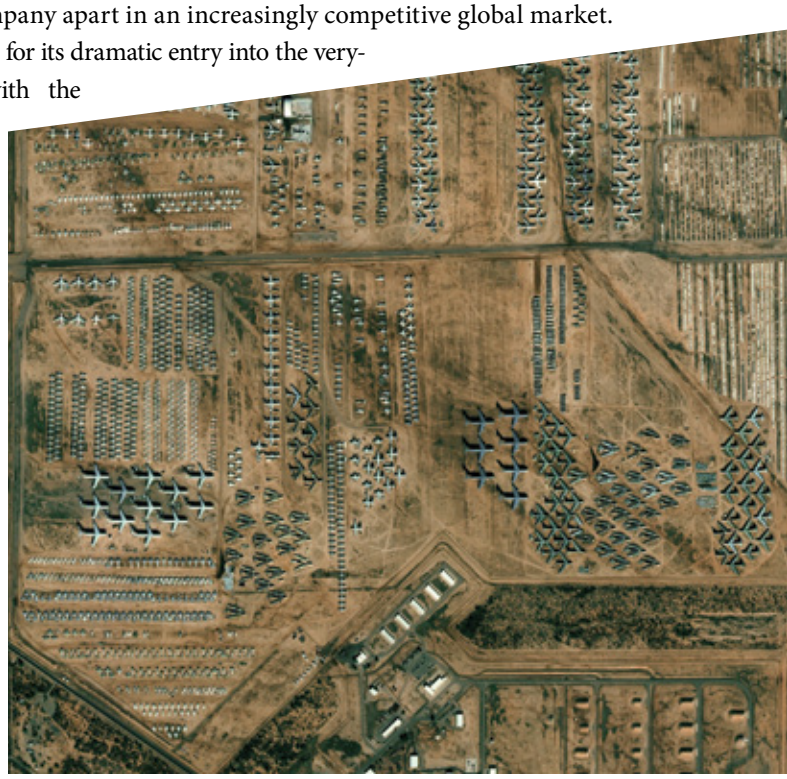
BY KEVIN P. CORBLEY, GEOSPATIAL BUSINESS CONSULTANT
CORBLEY COMMUNICATIONS INC. / DENVER, COLO.
WWW.CORBLEYCOMMUNICATIONS.COM

With three satellites launched in less than a year and a fourth slated for 2014, the GEO-Information division of Astrium Services has begun writing yet another chapter in its 30-year success story of providing high-quality commercial Earth observation products and services. A growing constellation of optical and radar satellites sets the company apart in an increasingly competitive global market.

Astrium Services has been widely praised for its dramatic entry into the very-high-resolution, sub-meter optical market with the Pléiades 1A and 1B satellites launched just 12 months apart. The company has been similarly lauded by the geospatial community for its commitment to high- and mid-resolution data continuity, punctuated by the SPOT 6 launch last September and preparation for SPOT 7 to join its twin in orbit next year.

The successful launches ensure a continuous stream of truly commercial multi-resolution, multispectral imagery well into the next decade. While sub-meter imagery and data continuity are crucial to the appeal of the Pléiades and SPOT satellites in a rapidly diversifying market for geospatial products, Astrium Services has introduced an important new theme to the story: unprecedented data access.

"Through nearly three decades of operating the SPOT satellites, we have learned that clients



▲ FIGURE 1.
Pleiades image of Tuscon, Arizona, 2011, showing multiple planes.
© CNES 2012 – Distribution Astrium Services/Spot Image.

Services

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▶ **FIGURE 2.**
Spot 6 image of Napa, California, 2012. © Astrium Services 2012. All Rights Reserved.

in all markets want faster and more direct access to image data, products and services," said Greg Buckman, Managing Director of Astrium Services' GEO-Information division in North America.

To make better data access a reality, the company has upgraded its technologies in orbit and on the ground. The satellites themselves were redesigned for greater agility, enabling collection of more imagery with vastly reduced scheduling conflicts. And the company has tapped the power of cloud technology to put same-day tasking requests in the hands of clients and to streamline delivery and management of end products.

The key component to improved data access—and an enhanced overall client experience—is the concept of the multi-satellite constellation unique to Astrium Services. Placed in phased orbits, the Pléiades and SPOT optical satellites are joining the TerraSAR-X and TanDEM-X synthetic aperture radar (SAR) platforms already in operation. With enormous daily geographic coverage, the satellites deliver an unprecedented stream of optical imagery and SAR data spanning multiple resolutions and spectral wavelengths.

"Each satellite in the three pairs has been designed to operate on its own, as a complement to its twin, or as part of the larger constellation with intra-day revisit capability," said Buckman. "This enables us to generate a matrix of multi-sensor products and services—including fused optical and SAR data sets—that is unmatched in the commercial Earth observation market today."

VERY-HIGH-RESOLUTION IMAGING

Launched in December 2011 and 2012 respectively, the very-high-resolution Pléiades 1A and 1B capture panchromatic and four-band multispectral data processed to generate standard 50-centimeter orthorectified color image products in 20x20-km scenes. The SPOT 6 and 7 sensors have been designed with improved resolving power over their SPOT 5 predecessor but still are in the

▼ FIGURE 3.
Bora Bora image taken by Spot 6, 2012. © Astrium Services 2012. All Rights Reserved.

same high-to-mid spatial resolution range. Imaging with a 60-km-wide footprint, SPOT 6 collects 1.5-meter panchromatic and 6-meter multispectral data.

The Pléiades satellites have been placed in a 180-degree phased orbit, as will be true of SPOT 6 and 7 when the second is launched next year. This creates a daily revisit for each pair over most locations on Earth. The Pléiades and the SPOT pairs will be phased 90 degrees from each other for a twice daily revisit among the four satellites. The SPOTs cross the equator at 10:00 a.m. solar time (for that part of the Earth) followed by the Pléiades just 30 minutes later.

"As expected, the sub-meter Pléiades imagery is in great demand for urban planning, military intelligence and civil engineering," said Laure de Saint Denis, Global Marketing Director for Astrium Services' GEO-Information division. "SPOT 6 data appeals to applications needing a balance between high-resolution and regional perspective, such as agriculture, forestry and general mapping." See *FIGURES 1-4* on pages 46-49.

In addition to rolling out new very-high-resolution image products generated from the Pléiades satellites, the company is leveraging the advanced SPOT 6 data to enhance its high- to mid-resolution offerings. The popular SPOTMaps color orthomosaics covering 100 individual countries, for instance, were originally created with 2.5-meter SPOT 5 data. They are now being upgraded with 1.5-meter imagery from the new satellite.

Already, clients in military, oil and gas development, and emergency response markets are using both Pléiades and SPOT datasets in combined applications to take advantage of their respective strengths. Disaster assessment may be the best example. Following an earthquake, for instance, SPOT 6 is relied upon to gauge the overall damage in the stricken region and to pinpoint hardest-hit sites. The Pléiades then zoom in on those priority areas so that appropriate relief can be deployed. See *FIGURE 5*.

ENORMOUS ACQUISITION CAPACITY

The most important technological advancement in both the Pléiades and SPOT series is the addition of Control Moment Gyroscopes (CMG) to the satellite buses. These allow the satellites to pitch and roll forward, backward and sideways up to 45 degrees very quickly—twice as fast as earlier designs. This remarkable agility enables them to capture a multitude of individual scenes, long strips, or broad

▼ **FIGURE 4.** New York City image taken by Spot 6, 2012. © Astrium Services 2012. All Rights Reserved.

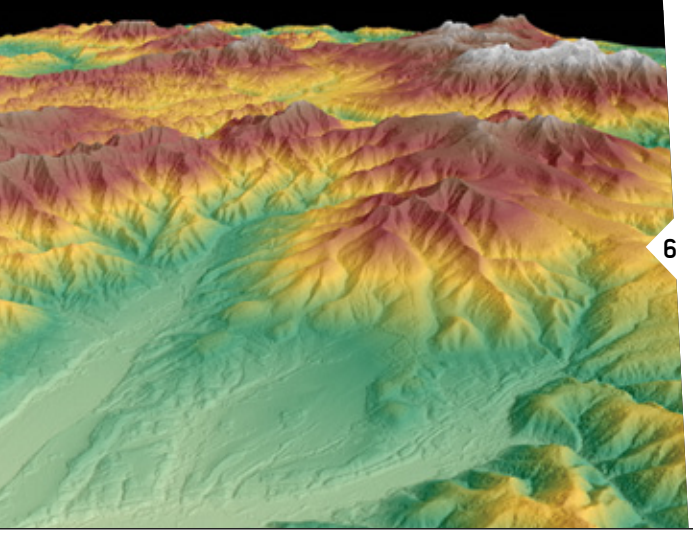
▼ **FIGURE 5.** Pleaides image of fires in Colorado, 2012. © CNES 2012 – Distribution Astrium Services/Spot Image.

Global Elevation Data

Astrium Services has expanded its line of elevation products thanks to the introduction of new and improved data sets. The GEO Elevation product suite relies on access to multi-resolution, multi-sensor data collected by optical and SAR satellites. Leveraging decades of experience deriving elevation products, Astrium Services now offers precise and reliable elevation data for any location on Earth ranging from global coverage to local detail. The four core elevation products are:

- *Elevation30 with 6-m horizontal and vertical accuracy at 30-m posting, based on DTED Level 2 standards*
- *Elevation10 with 5-m absolute height accuracy at 10-m grid spacing based on DTED Level 3*
- *Elevation4 with 3-m vertical accuracy at 4-m spacing*
- *Elevation1 with 1.5-m vertical accuracy at 1-m posting*

In the future, customers will benefit from the new worldwide high quality elevation product: WorldDEM. This global dataset will be available from 2014 for the entire Earth's land surface – pole to pole.



◀ **FIGURE 6.** WorldDEM of Hokkaido, Japan. © Astrium Services 2012 – Infoterra GmbH

contiguous areas of interest (AOI) on a single pass. The CMGs effectively extend the swath widths to 120 km for Pléiades and 300 km for SPOT.

"We can collect twice as many scenes on a single pass thanks to the CMGs," said de Saint Denis. "This has improved customer access to their areas of interest by reducing contiguous acquisition conflicts with other tasking requests."

Another advantage of the highly agile satellite design is the ability of the Pléiades and SPOT satellites to collect tri-stereo imagery on the same pass. In addition to collecting two oblique images looking forward and backward over an AOI as SPOT 5 did, each new satellite can pivot fast enough to acquire a third vertically over the target.

"This nadir image in the tri-stereo dataset vastly enhances the quality of elevation data extracted from the stereo images," said de Saint Denis.

She explained that in standard two-image stereo products acquired over steep terrain or dense metropolitan areas, low-lying features may be hidden from view in the oblique perspective by high mountains or tall buildings. In tri-stereo, the nadir image peers straight down into the natural or man-made valleys to capture all features and ground surfaces, resulting in more complete and accurate DEM datasets.

RADAR ASSET

As noted, Astrium Services' satellite portfolio includes two SAR satellites, TerraSAR-X and TanDEM-X, launched in 2007 and 2010 respectively as a joint venture of Astrium Services and the German Aerospace Centre (DLR). With a maximum spatial resolution of 1 meter, both satellites operate in the X-band wavelength and have adjustable swath widths of up to 150 km.

The primary differentiator between optical and SAR sensors is that radar systems are active systems transmitting radar pulses to the ground with the ability to collect data day or night in almost any weather conditions, including heavy clouds. For these reasons, TerraSAR-X is used extensively for applications in regions where cloud cover or seasonal darkness thwart optical image collection, including defense and security applications, as well as mapping and emergency response. Maritime surveillance is also a major market, including ship detection & tracking, oil spill monitoring, and sea ice tracking.

TerraSAR-X and TanDEM-X fly in a unique satellite formation only a few hundred meters apart forming a high-precision radar interferometer in space. The two

satellites record data absolutely synchronously acquiring the data basis for a homogeneous global Digital Elevation Model (DEM). With elevation points captured every 12 meters (referred to as 'posting'), this WorldDEM offering will be available from 2014 and features the highest resolution DEM with global coverage ever compiled.

"Clients will be able to purchase elevation data off-the-shelf from the WorldDEM for any land area on Earth with coverage as large as entire continents," said de Saint Denis. See *FIGURE 6*.

ALL-WEATHER OPERATIONS 24/7

TerraSAR-X offers a weather-independent site-access time of 2.5 days (2 days with 95% probability) for any point on Earth and a repeat cycle of 11-days. With radar monitoring services becoming increasingly in demand, especially over maritime regions, Astrium Services aims to improve the revisit time and increase data acquisition capacities. The company recently signed an agreement with Hisdesat, the Spanish government satellite service operator, to establish a Virtual Constellation with the TerraSAR-X and the Spanish PAZ satellite.

Scheduled for launch in 2013, PAZ will be placed in an offset orbit to TerraSAR-X to cut the revisit time in half. Operating these two virtually identical satellites in a constellation will afford Astrium Services and Hisdesat with a more flexible capacity management of their systems. Shorter revisit times and increased capacity will provide improved levels of responsiveness and acquisition opportunities worldwide, offering improved SAR capabilities for precise monitoring and detection of surface movement phenomena.

ENHANCED MONITORING ONSHORE AND OFFSHORE

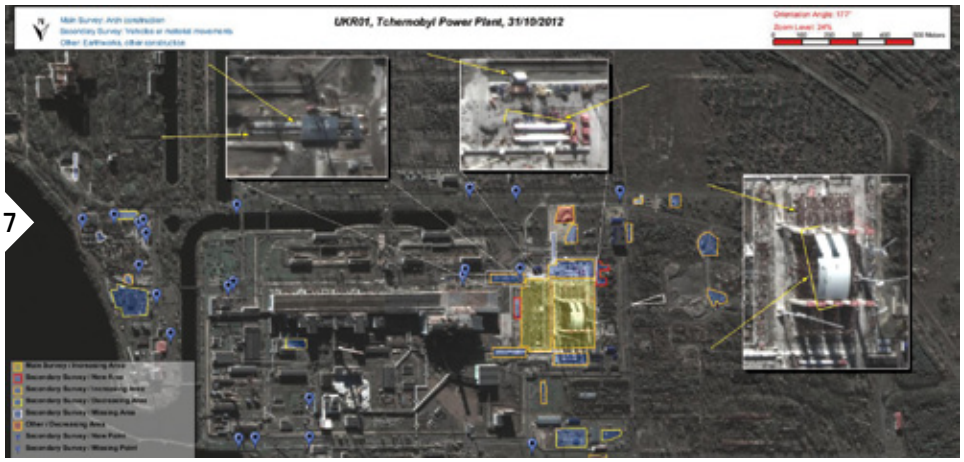
With three advanced optical and two SAR satellites now in its portfolio, Astrium Services continues to upgrade its lines of products and services. For clients, the most significant of these may be its enhanced change detection service, now called Go Monitor.

"With Go Monitor, our clients contract us to acquire image data over the same AOI repeatedly on the revisit schedule that makes the most sense for their application," said Buckman, "Natural resource monitoring may require quarterly collection, for instance, while defense and public safety might want twice-daily revisits." See *FIGURES 7-8*.

As part of Go Monitor, Astrium Services collects imagery over certain political hot spots around the world. Otherwise, clients select their AOI and satellite combinations, with an increasing number asking for SAR acquisitions to supplement the other platforms when darkness or clouds impede optical imaging. In some monitoring applications, however, SAR detects subtle changes that optical satellites can't and radar is the primary collection method.

"In the oil and gas industry, we have clients monitoring their production facilities with TerraSAR-X data for surface uplift or subsidence as small as a few millimeters, which could indicate potential problems and endanger facilities and human life," said Buckman. See *FIGURE 9*. "Our defense clients have found that SAR data can detect even the slightest disturbances in gravel and dirt road surfaces, tipping them off to vehicle movement around a specific location."

One of the biggest recent growth areas for the Go Monitor service has been offshore where the broad swath of the TerraSAR-X satellite quickly locates vessels that can then be identified with very-high-resolution



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▼ **FIGURE 7.** Go Monitor was utilized at the Tchernobyl Power Plant for arch construction, monitoring vehicles, and material movement. Image taken Oct. 31, 2012. Pléiades satellite image © CNES 2012 – Distribution Astrium Services/Spot Image S.A.

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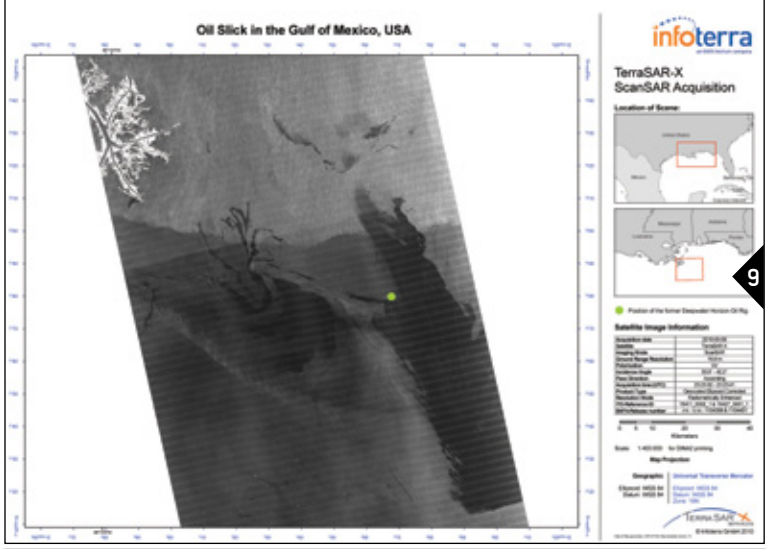
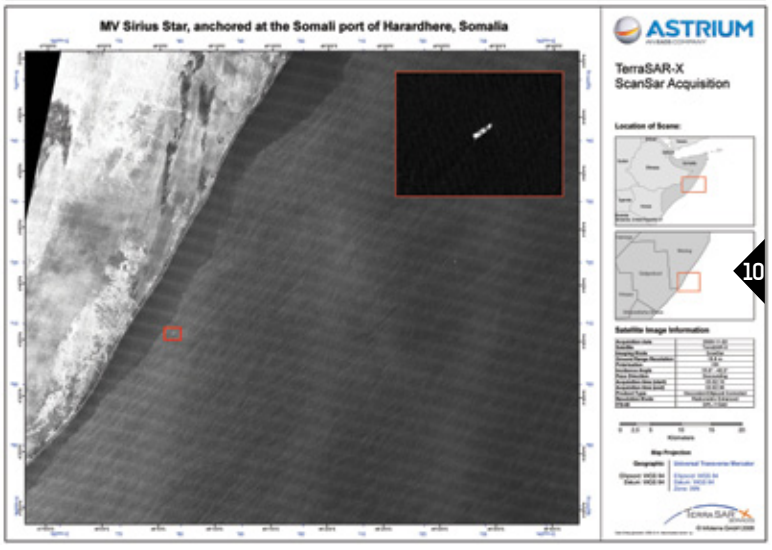
◀ **FIGURE 8.** Go Monitor was used for construction and production activities on Kharg Island. Image taken Dec. 1, 2012. Pléiades satellite image © CNES 2012 – Distribution Astrium Services/Spot Image S.A.





▲ **FIGURE 9.** TerraSAR-X image of an oil slick off the Gulf of Mexico, taken Aug. 5, 2010. © Astrium Services 2010 – Infoterra GmbH.

▲ **FIGURE 10.** MV Sirius Star in Somali waters, imaged by TerraSAR-X. © Astrium Services 2008 – Infoterra GmbH.

Pléiades imagery. Nations have begun using this service as advance warning of foreign ships approaching their shores, and international shipping companies monitor their own vessels worldwide to track their safe navigation. See *FIGURE 10*.

Monitoring ships in open water has become such an important part of the Go Monitor service that Astrium Services plans to increase the swath of the next-generation TerraSAR-X satellites to 400 km and add a maritime signaling receiver (AIS, or automatic identification system). This will enable the future radar satellites to instantly differentiate ships that are operating legally from those that may not be.

LEVERAGING THE CLOUD FOR SATELLITE TASKING AND DATA MANAGEMENT

To further facilitate client access to products and services, Astrium Services unveiled its online GeoStore in 2012. Developed with state-of-the-art cloud technology, this easy-to-use portal lets clients select an AOI and view available Pléiades and SPOT data in the archive, with TerraSAR-X being added soon. Accounts can be established so that personnel from client organizations can place orders and pay for products online any time.

One of the most innovative features of the GeoStore is the Instant Tasking option. As one of three options for ordering new acquisitions by Pléiades and SPOT satellites, Instant Tasking allows clients to task the satellite of their choice just hours before it passes over their AOI, allowing the end user to exploit an opening in weather conditions or catch an unexpected event on short notice.

"We've created three daily programing windows for Pléiades and six for the SPOT satellites," said Buckman. "That means an Instant Tasking client is never more than eight hours from tasking a Pléiades acquisition or four hours from a SPOT collect."

Any time of day or night, the client uploads AOI parameters and receives a list of overpasses for each optical satellite in the coming seven days. Instant Tasking also puts the client first in line for priority acquisition and product delivery.

In the other two tasking options, the client can use the interface to automatically collect the next standard 20x20-km Pléiades image that fits the client's criteria. Or the client may select the acquisition of a Pléiades or SPOT scene with tailored AOI parameters.

Another data access challenge facing many geospatial imagery end users today is the problem of big data. Acknowledging that more satellites with higher resolutions create more complex problems related to storing, managing and searching the data, Astrium Services has rolled out a new suite of Cloud Services. "Our Cloud Services are designed to make it easier and less expensive for clients to access and maintain geospatial data," said Buckman.

In its simplest deployment, these services give clients the option to stream their Astrium Services data, allowing them to access it from anywhere and from almost any device. In addition, clients can directly connect to the Astrium Services product catalog and order imagery with advanced processing. But what really makes the Cloud Services powerful is image data hosting. Organizations with large data archives can have their datasets hosted and maintained in the cloud on a secure third-party server with the data streamed live directly to any authorized end user in the enterprise at any time in any location.

"The bottom line benefit of Cloud Services is that they increase the overall value of imagery by extending data access across the enterprise," said Buckman. ∧○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Satellite Missions Improve Water Estimates

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

FRESH WATER IS HUMANITY'S SINGLE MOST CRITICAL RESOURCE.

According to a recent United Nations report, stresses on water supplies aggravated by climate change are likely to cause more conflicts, and water should be considered as vital to national security as defense. The report points out that 145 countries share watersheds with neighbors and there are more than 300 transboundary aquifers from which groundwater can be extracted.

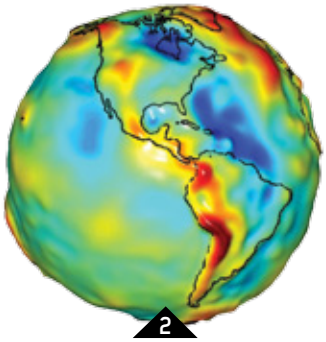
Yet, we still do not fully understand how much water is available and how it is distributed, which is a requirement for planning how to deal with changes in climate and, particularly, in rainfall. This knowledge gap is due to limitations in the relevant science and technology, the vastly insufficient number of sensors deployed around the world, especially in developing countries, and data denial by many governments due to security concerns.

Satellites, however, are dramatically changing this picture, by enabling us to measure the total mass of water on Earth and its various components, as well as to monitor how these amounts change over time. They are providing "the sole body of information that we wouldn't otherwise have," says Dr. Jay Famiglietti, Professor of Earth System Science and of Civil and Environmental Engineering at the University of California at Irvine and Director of the university's Center for Hydrologic Modeling, who has been studying the subject for more than 30 years.

Globally, new knowledge about water from satellites gives us insights into current conflict and future international security issues. Locally, it greatly improves the science and the practice of water resource management.

WATER-RELATED SATELLITE MISSIONS

The vast majority of water on Earth is surface water—in oceans, seas, and lakes. The rest is distributed between atmospheric moisture, soil moisture, deep underground aquifers, snow, ice sheets, and sea ice. NASA satellite missions employ different sensors and techniques to measure each of these water reserves. They include:



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- **GRACE (Gravity Recovery and Climate Experiment), launched in 2002, which maps gravity to detect the changes in total mass of water in large regions, and GRACE-FO (GRACE Follow On), scheduled for launch in 2017; they are both joint U.S.-German projects. See *FIGURE 1*.**
- **SWOT (Surface Water and Ocean Topography), scheduled for launch in 2020, will map surface water by measuring its height using radar; it is a collaboration between NASA, CNES (Centre National d'Etudes Spatiales, the French Space Agency), and CSA (the Canadian Space Agency). AirSWOT will calibrate and validate the radar for the SWOT mission, by deploying it aboard aircraft.**

Other water-related NASA missions are TRMM (Tropical Rainfall Measuring Mission), launched in 1997, to be followed by GPM (Global Precipitation Measurement), scheduled for launch in 2014; ICESat-2 (Ice, Cloud, and Elevation Satellite-2), for ice sheets and sea ice, scheduled for launch in 2016; GLISTIN-A (Airborne Glacier/Land Ice Surface Topography Interferometer), flown in 2009 and proposed as a spaceborne mission; and AirMOSS (Airborne Microwave Observatory of Subcanopy and Subsurface), which began in 2012. Scheduled for launch in 2014, SMAP (Soil Moisture Active Passive) will use a radiometer and a synthetic aperture radar (SAR) to provide global measurements of soil moisture and its freeze/thaw state. Another NASA sensor, MODIS (Moderate Resolution Imaging Spectroradiometer), which is a key instrument aboard the Terra and Aqua satellites, has been effective at collecting data on snow and there are plans for a Snow Water Equivalent-specific sensor. However, this article focuses only on surface and ground water.

▼ **FIGURES 1.** The GRACE satellites before launch. Courtesy of Astrium.

1

▶ **FIGURE 2.** GRACE gravity model of The Americas. Image courtesy of University of Texas Center for Space Research and NASA.

GRACE

The GRACE mission consists of two satellites, operating together as an instrument to map Earth's gravity and, therefore, its mass. They are in the same orbit at an elevation of about 500 km and at a distance of 220 km from each other. When the lead satellite flies over an area with above-average mass, such as a mountain range or a large amount of underground water, it dips lower, due to the additional gravitational attraction exerted by that mass; conversely, when it flies over an area with below-average mass, such as an ocean trench, it will rise a little higher. Its twin, following behind in the exact same orbit, will do the same. Therefore, by continuously measuring very precisely the distance between the two satellites, scientists are able to map the distribution of the Earth's mass.

In turn, this allows them to map water, because most of the big motions of mass are in the water cycle, explains Dr. Michael Watkins, manager of the Science Division at NASA's Jet Propulsion Laboratory (JPL) and Project Scientist for the GRACE and GRACE Follow-On missions. "For example, ocean tides, big flooding events, or tropical monsoons—that's a lot of mass! It can be up to billions of tons of water mass, actually—and those events, averaged over some time, are enough to actually move the satellites in their orbits."

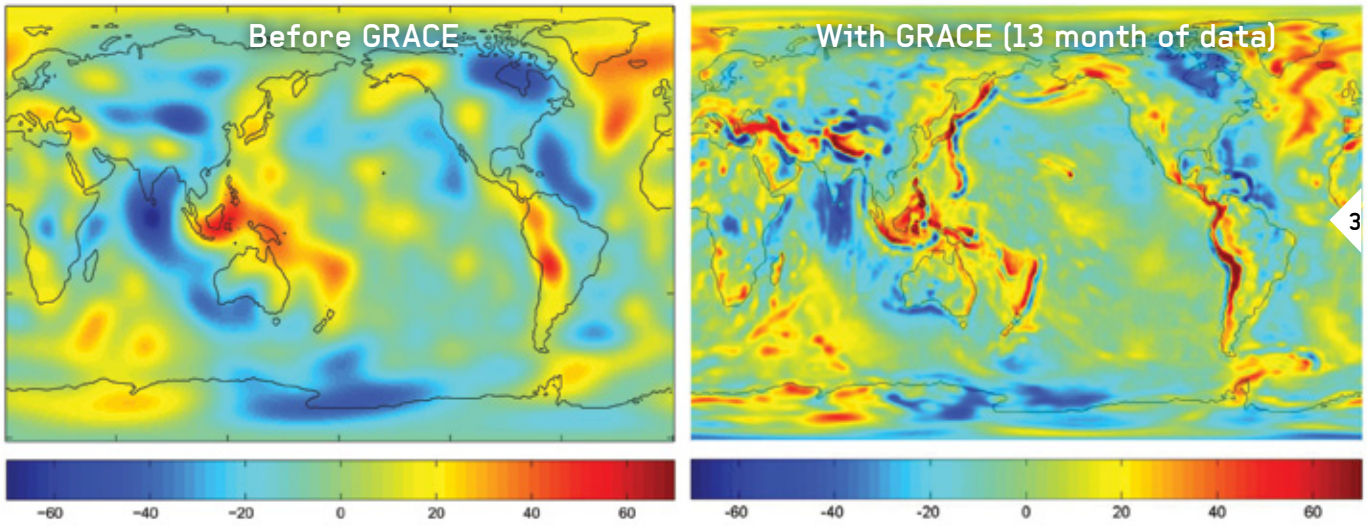
Because of both what it does (using changes in gravity to map the Earth) and how it does it (using satellites not just as platforms for instruments but as the instruments themselves), GRACE is a first-of-a-kind mission. "It's not often that you see a new remote sensing technique introduced from space like this," says Watkins. See *FIGURES 2-3*.

Jointly funded by the U.S. and German governments, GRACE was designed for a five year mission, but it just passed its 11th year. "It actually is aging," says Watkins. "It does not operate throughout the whole year now, because of some battery degradation. So, we are concerned that it will stop collecting data in the next couple of years."

Using a microwave link, GRACE measures the change of distance between the satellites at micrometer resolution. "The mission scientists need to know the change in the distance between the centers of mass of the two satellites," explains Albert Zaglauer, Project Manager at Astrium GmbH, the German company that built the satellites. "However, the measurement principle only allows you to measure the distance between the phase centers of the two antennas. So, you have a very accurate measurement of a distance of 220 km with a micrometer resolution between the phase centers of the antennas, but on each satellite, between the phase center of the antenna and the center of mass of the satellite, there's another 1.5 m and no one knows exactly how this distance is changing." Therefore, in order to preserve the measurement accuracy, Astrium used a combination of high-tech carbon fiber and ceramic material to build a system that is mechanically extremely stable.

Another mission-critical challenge was to de-correlate the effects on the satellites of gravity changes from those of surface forces, such as atmospheric drag or the pressure from the Sun's radiation, which can mimic changes of the Earth's gravity field. This was accomplished by deploying aboard each satellite an extremely precise accelerometer, called SuperSTAR, with a resolution of 0.1 nano g and better, explains Dr. Pierre Touboul, Director of the Physics Branch at ONERA

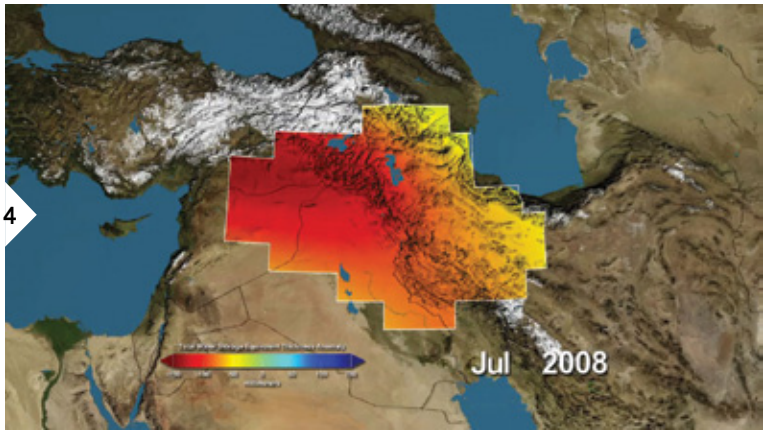
▼ **FIGURE 3.** Before the launch of NASA's GRACE satellite in 2002, knowledge of gravity was based upon decades of data from geodetic satellites (left image). Monthly gravity measurements are possible now that are 100x more accurate than previous models. The map on the right was produced after only 13 months of GRACE data.



(Office National d'Etudes et Recherches Aérospatiales), the French national aerospace research center, which built the devices. Like the satellites themselves, the accelerometers were also built for a five year mission but are still operating well, he says.

To improve the resolution, on future GRACE missions, NASA will replace microwave ranging with a laser system, enabling a better interferometer, Watkins explains, because laser wave lengths are about 1 micrometer, or 10,000 times smaller than those of microwave radiation. "So, instead of measuring the distance between the two spacecraft to micrometers, we will measure it to nanometers, almost atomic distances."

"Understanding the storage changes all over the Earth has been really, really critical," says Famiglietti. "Previously, we've been able to measure inflows and outflows but not the storage changes. So, we have a huge amount of uncertainty and error that accumulates. With GRACE we have an opportunity to measure those storage changes. Having this synoptic picture from satellites and finally being able to put it together is going to provide us with a whole bunch of new information. It opens up a lot of very interesting science in climate, hydrology, eco-hydrology, and the science of water resources management."



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▲ FIGURE 4. The Middle East had major losses in water storage, shown here in millimeters from Jan. 2003-Dec. 2009. Red shows drier conditions, with blue showing wetter conditions. The majority of the water loss was due to reductions in ground water due to human activities. Image credit: NASA/UC Irvine/NCAR.

"GRACE can be seen as a climate research mission," Watkins points out. "It helps us understand why Greenland ice is melting or why we have large-scale precipitation and water cycle changes. In addition, because you get this unique measurement of ground water, there are applications for water security and water management." See *FIGURES 4-5*.

SWOT AND AIRSWOT

The SWOT mission brings together U.S., French, and Canadian members of two scientific communities: hydrologists, who study terrestrial surface waters, and oceanographers, who study the world's oceans. It will make the first global survey of Earth's surface water, observe the fine details of the ocean's surface topography, and measure how water bodies change over time. It will also benefit studies of ice sheets and of sea ice, because by measuring how much sea ice is sticking above the water, scientists can infer how much of it is below the water. JPL will analyze the data collected by the SWOT satellite.

The SWOT mission will be the first one to map in detail where surface fresh water is, where it is going, where wetlands, lakes and reservoirs are, and how the distribution of water is changing—a subject about which we have "very poor knowledge," says Dr. Delwyn K. Moller, Senior Engineer at Remote Sensing Solutions, Inc., Principal Investigator for the AirSWOT radar payload, and a member of the SWOT Science Definition Team. "We have no picture of global surface water inundation, how it changes over time, how water moves up and down, how it spreads out laterally over the surface," says Famiglietti. "We hope to be able to understand how the heat of the ocean is transported, both vertically and horizontally, and that affects how climate change will affect the Earth," says Dr. Ernesto Rodriguez, Principal Investigator for AirSWOT and Payload Scientist for the SWOT mission at NASA JPL.

SWOT will deploy a Ka-band synthetic aperture interferometric radar, which is a new technology, operating at a wavelength of approximately 8 millimeters and a center frequency of 35.75 GHz. The technology in those frequencies has developed rapidly and has made it feasible to build a boom structure only 10 meters wide, Moller points out, making it possible to have a single-satellite solution. (By comparison, the boom on the Space Shuttle for the Shuttle Radar Topography Mission, or SRTM, was 60 meters wide.)

The satellite, which will have two antennas, will transmit out of one and receive on both, explains Dr. James R. Carswell, president of Remote Sensing Solutions, Inc. "By doing so, they can basically use triangulation in the simplest form, measuring very accurately the phase of these very high frequencies so the return can estimate the angle of arrival and then, therefore, measure the topography." See *FIGURE 6*.

The SWOT radar, called KaSPAR (Ka-band SWOT Phenomenology Airborne Radar), which is now flying as part of the AirSWOT program, actually consists of six Ka-band SARs all packaged together, says Carswell.

"It will obtain measurements like SWOT from near-nadir out to about 8 degrees, being able to map surface water height to 2 centimeter uncertainty. But then it has an extended swath that goes all the way out to 30 degrees incidence. This enables it to not only help validate the SWOT measurements but also to start seeing large features, such as eddies, that scientists using the SWOT measurements will be studying. It is going to be providing surface water topology with about 2 centimeter uncertainty over that swath."

Previous missions, such as TOPEX/Poseidon and the Jason series of oceanography satellites, were and are great in terms of showing us ocean currents and heat transportation, says Moller. This mission, however, "takes things to the next level," she says. "Previous missions are limited in their spatial coverage and resolution since they are profiling sensors. Because SWOT is an imaging mission, it will allow us to resolve the meso and submeso-scale circulation features at scales down to 10 km. We are trying to get down to centimeter level, on a 10 km scale. Over the land, the spatial resolution will be greater (50 m), with a relative water height accuracy of 10 cm. Currently, hydrologists have no data even close to this level of resolution; therefore, SWOT will be a transformative mission."

GROUND-BASED SENSORS

To get the full picture about water, scientists also need the best available data on the ground—from stream and rain gauges, soil moisture stations, snow monitors, sensors in ground water wells, and so on. In addition to helping to validate the satellite data, this *in situ* data "is more reliable and more continuous and is at a high enough resolution and density in space and time that it can really help us manage water where people live," says Famiglietti. "In science, most of us are driving toward trying to combine all of this stuff into detailed models that will integrate the ground-based data and the satellite data and put together a complete picture of how water is distributed, laterally and vertically. We can't do that without ground-based measurements. The best places to put sensors are where the change is most rapid or where the most people live."

COMBINING SOURCES AND TECHNIQUES

The challenge for scientists is to figure out how useful each of these different technologies is and to combine the data as effectively as possible.

Depending on the sensor, the resolution can vary

> As the technology improves and hydrologists figure out how to use it better... the data denial policies of many countries will become obsolete. It's going to be in everyone's best interest to contribute data and use it to their advantage.

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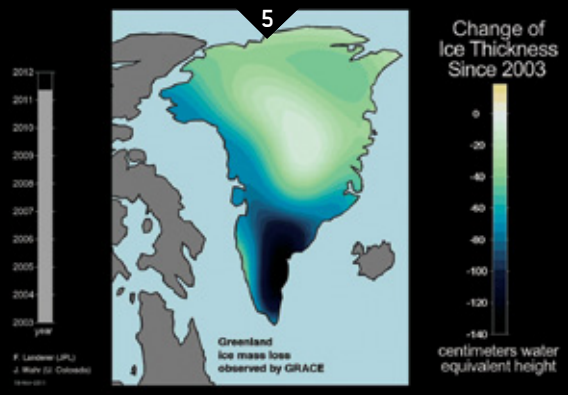

◀ **FIGURE 5.** GRACE measures changing ice mass of Greenland, which has had major reductions, shown here. Image credit: NASA/JPL-Caltech/ University of Texas Center for Space Research.

▼ **FIGURE 6.** Artist's concept of NASA's SWOT satellite, planned for launch in 2020. SWOT is designed to make the first-ever global survey of Earth's surface water—lakes, rivers and ocean—collecting detailed measurements of how water bodies on Earth change over time. Courtesy of NASA/JPL-Caltech.

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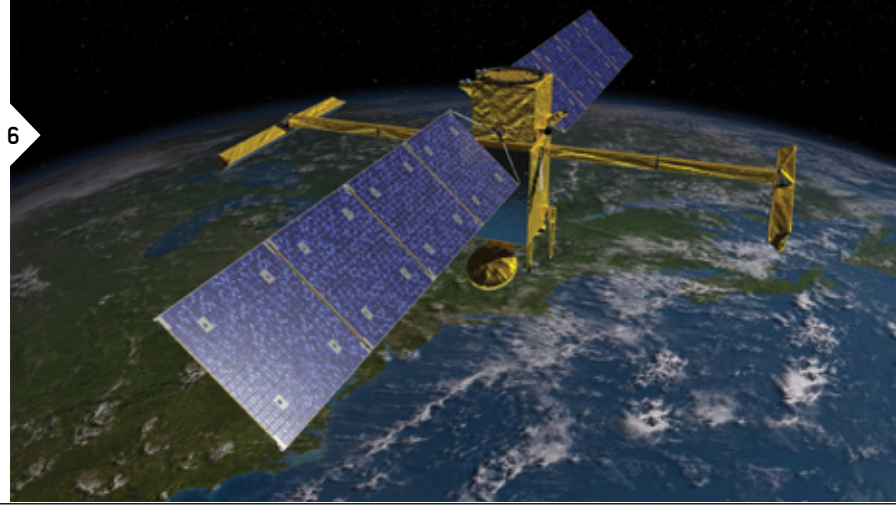

from meters to hundreds of thousands of square km.

GRACE has a spatial resolution of 150,000 sq km or greater and a time resolution of months or longer. "So, it's not going to tell anybody how wet the soil is in the center of the University of California at Irvine campus tomorrow," Famiglietti points out. "But it is going to tell us overall storage changes in Southern California for the month of March. Other sensors—like SWOT, for example—will be measuring at much higher resolution and will actually be able to see within a major reach of a channel what the flood plain inundation looks like and how it changes during the course of a seasonal storm that might last for a few days. Ultimately, the combination of something like SWOT with GRACE and SMAP will really provide just an incredible amount of new information." Once you subtract the data from SWOT and SMAP from the total amount determined by GRACE, the rest has to be below the root zone, he explains. "That's huge, actually."

"The water storage over a large area has to add up and be constrained to what GRACE is observing," says Watkins. "The combination of highly local and very precise data with the very precise GRACE large-scale data makes a unified product. So, the cutting edge people are putting all of this data together in a big model constrained by GRACE."

CONCLUSIONS

Satellites provide a global picture that doesn't know any political boundaries. "We're able to really see what's going on," says Famiglietti. "In particular, with water, we can understand what all the stress points are—whether they point to heightened conflict in the future or to opportunities for collaboration. As the technology improves and hydrologists figure out how to use it better and construct better and better pictures of where the water is, the data denial policies of many countries will become obsolete. It's going to be in everyone's best interest to contribute data and use it to their advantage. Ultimately, we'll see—maybe in the developing world or in conflict-prone regions—a lot of people may use water as a means to collaborate, rather than to fight."

The water-related missions undertaken by NASA and its partner agencies are rapidly expanding our knowledge of water at a time when the twin challenges of climate change and population growth are making this knowledge a key to reducing conflict worldwide.

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