SERIES: Filling the Gap

Data Management and Visualization Solutions from CartoDB & DigitalGlobe, and NGA Weighs In

“The next major revolution will be on the ground, with data exploitation and the ability to build sustainable businesses on top of the unique information feed that comes from space, and to match it up with data collected on the ground.”

– Robbie Schindler, Planet Labs, p. 22

“Previously, only GIS experts knew methods to deal with this challenge, but now data scientists increasingly have access to those tools, and GIS in business enterprises is getting closer to being a data science.”

– Andrew Hill, CartoDB, p. 16
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FOR THE CONFLICT-RIDDEN African country of Nigeria, relatively peaceful presidential and gubernatorial elections occurred in March and April 2015. However, that summer, floods occurred from rainfall, which are documented by Commercial Synthetic Aperture Radar satellite TerraSAR-X.

This image is a 3-meter Stripmap showing flooding on the ground in the areas marked in red. Image dates: May 5, 2015 and Sept. 1, 2015. Copyright: DLR e.V. 2015 and Airbus Geo GmbH 2015.
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DEAR READERS,

In this issue, we are continuing our series, “Filling the Gap”… that is, the gap that will be left when Google ends support for Google Earth Enterprise (GEE) on March 22, 2017. (The Google Earth API and Google Maps Engine are also no longer supported. Google is clearly still committed to Google Earth Engine and other products, which we will cover in a future issue.) The genesis of this series was to offer users of GEE many options for the future, signs for your roadmap, a sense of a new direction.

In Fall 2015, we covered Esri’s ArcGIS Earth, and VRICON’s Globe in 3D. In Winter 2016, we featured Galdos Systems’ INdicio, Skyline Software’s SkylineGlobe and TerraExplorer, as well as Onix Networking Corp., which integrates Skyline’s software into organizations’ IT systems. In this issue, we add CartoDB and a bit about DigitalGlobe (more to come in Summer), and we also asked experts from the National Geospatial-Intelligence Agency to weigh in. Read the article on page 16.

While DigitalGlobe is included in this, our 3rd installment of the series, “Filling the Gap,” it should be noted that the Summer issue will provide more information on how their new Geospatial Big Data Platform (BGDX) and Maps API will meet the needs of some customers. We will help you understand the points of differentiation.

In this issue, not a moment too soon, Apogeo Spatial is finally featuring the innovative satellite Earth imaging company, Planet Labs. The company was founded in 2010 by a team of ex-NASA scientists (several of whom were students of Apogeo Spatial editor Ray Williamson, when he was teaching at George Washington University, or at the International Space University). The mission is to image the entire Earth every day, and make global change visible, accessible, and actionable. They started as a small team of physicists, and aerospace and mechanical engineers in a garage (pictured on page 27), using the cubesat form-factor to inform the first designs of the Dove satellite. Read our interview with Planet Labs’ co-founder Robbie Schingler and VP of Global Impact Initiatives Andrew Zolli on page 22.

Finally, after many years of discussions and unused licenses and false starts, and after a decade of organizations relying on Canadian and Italian commercial Synthetic Aperture Radar (COMSAR) satellites, a few U.S. companies are planning to launch COMSAR satellites. Plans for XpressSAR are discussed on page 11, with a quick glance at the history of U.S. policy (or lack thereof) for COMSAR.
I spent the last few days at the annual general assembly of the European Geosciences Union. The level of expertise and the abundance of knowledge gathered at this conference – like at many other similar conferences – is astounding. Anybody coming from another planet and experiencing this would likely come to the conclusion: they have all the knowledge required to be the stewards of the planet ensuring the functioning of the planetary life-support system for all.

But if this alien would take a look around, it would be immediately obvious that we are rapidly and irreversibly degrading our life-support system, on which we and all future generations depend. I assume, the alien would be at a loss: Why do they not use their knowledge for a responsible and sensitive stewardship?

The planet like the rest of the universe is governed by natural laws. These laws are the basis of the life-support system that is maintained on Earth. The life-support system is in a delicate homeostasis that can be impacted by large hazards (extreme volcanic eruptions, impacts of large asteroids), slow changes (in land distribution, land cover, and incoming radiation), or minor changes in the large mass cycles that constitute the physiology of the life-support system.

Whenever significant changes in the life-support system happen, the biosphere reacts, often with increased extinction rates, and the biosphere changes. Earth observations document fundamental changes in the life-support system caused by what I tend to call the Anthropogenic Cataclysmic Virus (ACV): more than 60% of the ice-free land surface has been changed:

- the chemical composition of the atmosphere and oceans are changing,
- the water cycle is impacted by reservoirs, redirected rivers, exploited aquifers,
- the Nitrogen cycle has been fundamentally changed,
- Phosphorous reserves are depleted to feed overpopulation,
- new chemical constituents are introduced into the environment, and
- species are genetically re-engineered at all levels.

Maybe worst of all, there is a belief that we can overcome all issues of the degradation of the life-support system with more innovation and a reduction of entropy in the built environment and the embedded social fabric.

Jacopo Simonetta takes a different look at the development of our high-energy,
While many cultures aimed at an economy based on a thorough understanding of the importance of a functioning life-support system, others totally focused on creating ways to basically unlimited wealth aggregation.\(^5\) By inventing virtual value, i.e. paper money, there was no physical limit anymore to how much wealthy individuals or single organizations could accumulate.

A particular example of the latter is our modern society dominated by the values of the North-Atlantic culture. Today, almost exclusively, economy is based on the “laws” that are defined by believers in capitalism, which could be described as the world’s largest religion.\(^6\) It has been said that the laws of capitalism are in conflict with the laws of nature. Others have pointed out that capitalist economy violates nature’s laws. However, nature’s laws cannot be violated. Nature is the best enforcement agency and no violation is accepted. Of course, some perpetrators manage to direct the punishment to others. But as a species, we do not have this option for long.

We have a focus on the immediate — be it rewards or threats. The most discussed impacts of climate change are natural hazards already felt today like droughts, heat waves, floods, hurricanes, and new infectious diseases. For sea-level rise, we discuss coastal inundation (which some call frequent nuisance flooding), coastal erosion, and more storm surges. Economic risk assessments are generally based on the physical damage caused by the hazards.\(^7\) Seldom do we try to imagine other impacts at social and economic levels.

\(^1\) What will be the costs of heading into a new dark age where our knowledge of a rapidly changing planet with new dynamics and new patterns is decreasing and resulting in limited forecasting capabilities?\(^8\)

\(^2\) To what extent is terrorism caused or increased because of environmental and economic injustice resulting from climate change and its consequences?
How much of the worldwide efforts to protect population from terrorism should be counted as costs of climate change?

The same questions apply to the rapidly increasing migration and the direct and indirect social, political, and economic costs of dealing with those pushing into the wealthier nations. Europe might be destabilized socially and politically by the challenge of finding an ethical way of dealing with the misery of the intruders and the pressure they put on the lives of the Europeans. The social and political changes resulting from migration both in the source regions and in the areas absorbing the endless stream of refugees, who are in dire need, are not yet counted as a fine for having acted in conflict with nature’s laws.

Importantly, what are the hidden risks for our current economic system? One such risk is seldom discussed, although there is little hidden about it – the risk of a global real estate bubble. In the last 100 years, urban population increased rapidly, and much of this growth happened in the coastal zone. Seventeen of the 24 mega cities (more than 20 million people) are in the coastal zone, most of them in low-lying areas. And these areas are the most rapidly expanding ones. In many coastal areas threatened by sea-level rise, the construction of new infrastructure and condo complexes reaches new heights. Even for the lower part of the range of plausible sea-level rise scenarios, this makes little sense beyond the immediate interests of the developers. But we gain more and more evidence from Earth observations and new models that the optimistic sea-level rise scenarios limiting the maximum to less than 2 m by 2100 are likely failing to capture the full risk spectrum. Considering the non-linear response of human beings to threats, it seems to be only a question of time until humans will lose the trust in the value of beach-front properties, and a global real estate bubble will impact the economy in unparalleled ways.

If I were the alien referred to above, I’d send a message home to get me out of here before the overload of complexity and the continuous violation of nature’s laws leads to “the collapse of everything,” to quote John Casti.

Endnotes:
Commercial Synthetic Aperture Radar (COMSAR) data has considerable value for multiple applications and missions. Global national security concerns reinforce the need for unified Combatant Commands (COCOMs) to have continuous awareness of their area of responsibilities. A United States commercial Synthetic Aperture Radar (SAR) capability that provides sharable GEOINT (geospatial intelligence) at any time and in any weather condition is critical to enhancing situational awareness and gaining a tactical edge.

The United States is increasingly undertaking military, humanitarian and disaster relief missions in coalition with like-minded partner nations. These multinational efforts have become a pillar of U.S. security policy. Coalition actions that share mission costs and responsibilities among partner forces are preferable over unilateral strategies. The key to their success is effective communication at all levels of operations and requires the exchange of critical information including GEOINT and MASINT (measurement and signature intelligence).

Unclassified commercial GEOINT is critical to coalition operations such as Countering Transactional Organized Crime (CTOC), Humanitarian Assistance/Disaster Relief (HADR) and defending against terrorist activity. In addition, civil applications such as environmental monitoring, safety of navigation, regulatory compliance and maritime domain awareness are all best supported and enhanced by robust use of commercial synthetic aperture radar.

Finally, the U.S. pivot to the Asian-Pacific region along with increasing threats to U.S. interests in Eastern Europe, South America and Africa only increase the need to work with varied coalitions. Many of these areas are subject to persistent cloud cover and require high-resolution sharable GEOINT and MASINT data.
The XpressSAR Constellation

In October 2015, the Virginia-based XpressSAR Inc. was granted a license by the Department of Commerce to operate a private, commercial, space-based, SAR remote sensing system. XpressSAR is the first 100% U.S.-owned company licensed to operate a commercial constellation of four high-resolution commercial X-Band SAR satellites capable of collecting data with a ground resolution of 30 meters to sub-meter.

The satellites will operate in an equatorially inclined orbit 48° North and South at an altitude of 425 km. Command, telemetry, mission control, processing and data storage will be in Florida. XpressSAR is designed to provide guaranteed multiple collections per day over the area of operation.

“The Genesis of the XpressSAR SAR constellation concept was the outcome of several years of meetings and discussions with various stakeholders such as the COCOMs, defense related agencies, U.S. civil governments, as well as Asian allies of the United States,” said Wolfgang Biedermann, XpressSAR’s CEO. “These discussions helped shape the mission and capability design of the constellation.”

The importance of SAR for COCOM commanders relates to the cloud persistent nature of their area of operation and the need to share high-resolution GEOINT information with U.S. coalition partners. Many of these COCOMs operate in the so-called “Arc of Instability,” which is the region of the globe where most conflict and terrorism exists. It also happens to be where the majority of the world’s energy and important raw materials reside and ocean commerce takes place.

“The XpressSAR mission has been optimized for the ‘Arc of Instability’ region of the planet,” said Tom Ager, XpressSAR Technical Advisor. This is a swath of territory running from the Caribbean Basin through most of Africa, the Middle East and Central and Southeast Asia. The challenge within the Arc is that certain nations possess oil, minerals and other strategic items that developed economies depend upon. They also occupy geopolitically important areas, have a majority of the population that is young and harbor the bulk of the world’s terrorist and insurgencies. In short, most of the regional hotspots today are within the Arc of Instability, which is also the cloud-belt area of the Earth.

The All-Weather Nature of SAR

SAR will allow observations of the Earth’s surface day or night, regardless of weather or cloud conditions. Unlike optical remote sensing systems, which rely on the sun for illumination, SAR provides its own illumination via microwave transmissions from the satellite. These transmissions are coherent, which means that both amplitude and phase information are retained. The sun’s illumination reaching the Earth is incoherent (scrambled), which means that only amplitude information can be used in an optical system. Clouds, weather and lack of sunlight impact the ability of optical systems from acquiring data.

The XpressSAR Mission Capabilities

Security concerns across the global landscape reinforce the need for continuous awareness over certain areas of interest. SAR is a capability that can provide intelligence imagery anytime regardless of the weather. SAR will enhance the U.S. government’s
capability through providing critical unclassified situational awareness. Applications that can be satisfied with XpressSAR include:

- Amplitude Change Detection
- Coherent Change Detection (detection of millimeters in surface change)
- Colorized Surface Texture Images
- Detected Images
- Repeat Pass IFSAR DEMs
- Sub-Aperture Products
- Subsidence Maps

Current COMSAR State of Affairs

Currently, all of the operational COMSAR systems are owned and operated by non-U.S. entities and are significantly supported by their respective defense ministries and governments. Since 2007, these systems have delivered high-resolution, high-quality X- and C-Band data products and worldwide direct downlink services.

Prior to October 2015, U.S. licensing policy applied more stringent controls on operation and dissemination of SAR systems and data than on optical systems. U.S. policy is particularly stringent in the handling of “phase history data,” which are the raw data collected by the satellite and are most valuable for advanced interpretation of image data. These restrictive data dissemination policies are a major reason why no U.S. firm has been able to effectively enter the global SAR market.

A key goal in 2006 National Space Policy was to “Enable a dynamic, globally competitive domestic commercial space sector in order to promote innovation, strengthen U.S. leadership, and protect national, homeland and economic security.” The United States is not leading, however, with regard to space-based commercial radar imaging systems. Although the U.S. government granted a 1-meter resolution radar-imaging license in 2000, the licensee was not authorized to sell better than 3-meter resolution imagery.

History of U.S. COMSAR Policy

1997: Former Sen. Dennis DeConcini noted, “No U.S. Company has been licensed to sell high resolution radar imagery.” Noting that 12 U.S. companies had been granted licenses since 1992, but none for radar, he argued, “if Commerce does not license a radar satellite system, then a foreign owned radar system, with a one meter or less capability, will enter the market leaving the U.S. government with no effective control in this area.”

1997: DoD opposes commercial sale of radar satellite imagery better than 5-meter resolution, due to national security.

May 1998: Former Sen. Tom Daschle wrote to the Pentagon noting, “If currently proposed restrictions on U.S. commercial remote sensing satellites are not revised, the capabilities of foreign SAR systems will quickly exceed those of the United States.”

June-November 1998: A U.S. company (Space Radar Corporation) obtains a license to operate a 1-meter resolution commercial radar satellite, but data sold could not be better than 5-meters.

November 2000: A second U.S. company (Ball Aerospace and Technologies) obtains a license to operate a commercial radar satellite, but resolution restrictions apply. Three-meter resolution imagery eventually is allowed for sale.

2004-2005: The Government considers, but does not issue a 1-meter commercial radar satellite license.

June-December 2007: Germany’s TerraSAR-X and Italy’s COSMO-Skymed 1 are launched with better than 1-meter capability.

October 2009: Department of Commerce authorizes commercial sale of 1-meter resolution radar imagery to Northrop Grumman.

October 2015: XpressSAR, Inc. receives the only license for sub-meter resolution to date.
imagery. Meanwhile, non-U.S. COMSAR suppliers significantly improved their capabilities. National Security Presidential Directive 27 (NSPD) states it is the policy of the United States to advance and protect national security interests by maintaining leadership in remote sensing and sustaining the U.S. remote sensing industry. Presidential Policy Directive 4 (PDD) states that the United States is committed to growth of a U.S. commercial space sector. The 2011 National Security Space Strategy states that the United States should rely upon proven commercial capabilities to the maximum extent practicable.

The new COMSAR companies (XpressSAR and others listed on page 15) provide an opportunity for the United States to promote the resurgence of an efficient, internationally competitive, U.S. commercial SAR remote sensing enterprise with a space mission that is cognizant of private sector growth and public sector capabilities. The XpressSAR system does not have the same secrecy restrictions as national assets; therefore, information generated by the constellation can be shared with U.S. allies and civil agencies. In addition, a U.S. SAR satellite constellation provides trusted resiliency and is a complementary addition to the nation’s fleet of GEOINT and MASINT satellites. See U.S. policy timeline on page 13.

The COMSAR Market

High-resolution Synthetic Aperture Radar has historically been restricted to the world of defense and intelligence and only used by a small club of nations. The commercial use of SAR began in 1995 with the launch of the Canadian C-Band system called Radarsat. Radarsat’s best commercial resolution was 3-meters at the time and thus restricted its usefulness to very specific markets like maritime applications and ice monitoring.

The high-resolution commercial market for radar began with the 2007 launch of Germany’s TerraSAR-X and Italy’s Cosmo Skymed, both of which are X-Band radars. These systems introduced to the market radar resolutions in the sub-meter range.

Since high-resolution radar is only nine years old, the market is in its early stages of development. As such, the primary market for high-resolution X-Band data and products are, for the short-term, still inherently governmental.

What does this mean to the adoption of commercial SAR data globally? As the value of high-resolution SAR becomes better understood the market will respond accordingly. Most observers of the Earth Observation industry tend to see the commercial market for high-resolution SAR increasing significantly between 2017 and 2023. One such observer of the industry, Northern Sky Research (NSR), in its report, Satellite-Based Earth Observation, 6th Edition, predicts a significant increase in the number of customers for high-resolution radar data over the next 10 years. According to the NSR report, this increase in demand for high-resolution SAR will result in an additional $130 million in annual revenues for the industry by the end of 2023.

The World Radio Communication Conference decision makers allocated new frequency bandwidths for X-Band Earth Observation Synthetic Aperture Radar systems by doubling the actual 600 Megahertz to now reach 1,200 Megahertz. This decision opens the door to unprecedented image resolution quality for future X-Band SAR satellites like XpressSAR.

With this larger frequency allocation, the next generation of X-Band SAR satellites will be able to offer high-quality sub-meter resolution imagery with increased quality to better analyze surface features such as infrastructures and vegetation. This will drastically improve applications such as surface movement detection due to more precise information on the unstable layers near the surface, or
maritime safety through detection of smaller vessels and refined identification of suspicious activities.

The strategic and tactical value of commercial SAR is finally being recognized and is beginning to take hold in the GEOINT community. From highly accurate global digital elevation and terrain models to maritime domain awareness to persistent surveillance in regions with chronic cloud cover, SAR provides capabilities and advantages over electro-optical imaging systems. Enhancing the future of SAR are new cost-saving technology, advances in data capture and processing and access to higher bandwidth enabling the acquisition and processing and dissemination of richer, more detailed data. Future SAR missions will provide better information and unprecedented image resolution quality, which will enhance our understanding of Earth, ocean, and atmospheric processes at lower costs than heretofore possible. 

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Companies Pick Up Where Google Earth Enterprise Leaves Off

NGA Comments on the Demise of GEE

By Matteo Luccio / Contributor / Pale Blue Dot LLC
Portland, Ore. / www.palebluedotllc.com
The waves created by Google’s announcement that it will stop supporting Google Earth Enterprise (GEE) in the spring of 2017 continue to ripple through the geospatial community. For this third installment in this series, I interviewed Andrew Hill, Chief Science Officer at CartoDB, a software vendor; John-Isaac Clark, Director, Product Management – Geospatial Big Data at DigitalGlobe, a satellite imagery and information vendor; and Lt. Col. Michael Russell, GEOINT Visualization Services (GVS) Program Manager at the National Geospatial-Intelligence Agency (NGA), one of the largest users of GEE.

**CartoDB: LIKE GEE, BUT WITHOUT A 3D GLOBE**

Several geospatial companies offer partial replacements to GEE, though their offerings differ somewhat from each other and from GEE. The biggest difference between CartoDB and GEE is that the former lacks a 3D globe. Instead, like Google Maps, it is focused on flat projections. CartoDB and GEE, however, share many features, Hill points out, including the ability to create multiple maps from a single dataset and for teams to collaborate around geospatial data. “GEE’s portability is a very valuable feature for enterprise users,” says Hill. “Many GIS tools are pretty heavy. They have many requirements about where they can be installed. Many of them don’t work very well on mobile devices. CartoDB solves many of the same problems as GEE.” CartoDB is a software-as-a-service, so it enables users to build apps and analyze data directly from their browsers, without installing any tools, and to access their work from mobile devices.

Both GEE and Esri’s ArcGIS Earth are built around the idea of presenting geospatial data on a 3D Earth and allowing users to navigate on its surface. By contrast, Hill says, “CartoDB is focused around drilling down into geospatial data and then gathering insights from that, but then also sharing those insights with other people.” He points out two important differentiators between CartoDB and the other two platforms. First, that the data in CartoDB resides on “a powerful back end” that can analyze that data and perform filtering, measurements, and other GIS functions. “Combining those features is what allows enterprise users to tap into and gain insights from their data,” says Hill. Additionally, he says, CartoDB’s ease of use allows people with very different backgrounds, including many without training in GIS, to look at their data, find patterns and outliers, and make some predictions.

CartoDB, Hill explains, has two major user groups, each defined by one subset of CartoDB’s functionalities. The first group consists of university users and people who use the free version of the software. “They tend to use CartoDB as a mapping platform, so they will load data into it, work with advanced cartography, and then publish a map,” says Hill.
The second group consists of enterprise users, who do such things as build analysis dashboards, integrate CartoDB’s geospatial back end with their own tools, and leverage the CartoDB platform at scale in their teams. “We have people who use CartoDB for everything from building geospatially-enabled data portals to building store locators, to performing analytical analyses with demographic data.”

Like GEE, CartoDB enables users to visualize their geolocated data on a map. “It’s pretty incredible how powerful that can be for enterprise users as the first step,” says Hill. “Many users have data that contains geospatial information that they have only ever seen in a spreadsheet.” Also like GEE, CartoDB enables users to run analyses on datasets that are changing in real time. “You could be looking at such things as clustering of customers, or the overlap of sales regions, or the performance of different neighborhoods in terms of real estate values and publishing such valuable maps internally,” Hill explains.

NGA’S TAKE ON GOOGLE’S DECISION

NGA has been utilizing GEE mostly on a classified level. “This is one of the major reasons why Google decided to distance itself from the U.S. Intelligence Community (IC) and from supporting the enterprise server the way it did,” says Russell. “Google wanted to change its code framework and appears to have determined that the separate instances they would be required to support in a system set up specifically for the Department of Defense and the IC was not in its best interests from a corporate perspective.”

If NGA was only going to utilize Google Earth in an unclassified way, he explains, the agency would simply stick to the free, public version of the platform and continue to run its programs on it. However, only a small percentage of U.S. military and intelligence users around the planet—generally those focused on humanitarian or emergency and disaster relief efforts—use Google Earth on the unclassified level. Most of them utilize the version of Google Earth that NGA makes available to them on the Department of Defense’s secret network, SIPRNet; many of them also use it on the top secret JWICS network.
The Google Earth version that NGA supports and that the GVS program office provides to the user community is accessed by 30,000-35,000 individual users every month and generally gets close to one billion hits per month by those users, according to Russell, supporting as many missions as there are unique users. He defines a “hit” as “any time a user changes an overlay or any particular set of imagery tiles during their workflow.”

On all security domains, GVS offers what it calls a “GIS portal,” which serves as a collaboration environment. However, Russell points out, it is only a 2D environment. “From a 3D perspective, really, the NGA GIS has been built on a Google Earth foundation.”

NGA’S TRANSITION OFF OF GEE

NGA has a longstanding collaboration with ESRI in the GIS field. GVS offers the IC Esri’s 3D-capable viewer ArcGIS Explorer. “It is more of an analytical tool, not widely used like Google Earth,” says Russell. While Google Earth provides a “common operating picture” for operation centers around the world, he explains, ArcGIS Explorer has been used mostly by analysts for analytical and exploitation activities and is more commonly focused on a particular area. As its main replacement for GEE, NGA will adopt Esri’s new platform, ArcGIS Earth. The way GVS will be using it, Russell says, is as “sort of a follow-on to ArcGIS Explorer.” It is currently in pre-beta testing with some of NGAs major users around the planet and will behave very similarly to Google Earth once it is fielded, he says. (Editor’s Note: This series featured ArcGIS Earth in our Fall 2015 issue.)

Many of NGAs users are very heavily dependent on Google Earth because over the past decade, they have built many services and data overlays on it using very loosely specified KML that is not supported by other 3D visualization providers. “So, while they display well on Google, they do not display well on other 3D applications,” says Russell. Handling that non-specific KML has been a focus area for the GVS development team, with help from ESRI personnel, so as to provide access to it for users over the next couple of years, during the transition from GEE to ArcGIS Earth. “It is going to take that long because a lot of development time and transition has to be built in for handling some of our larger customer needs,” Russell explains.

To support this transition, GVS has teamed up with Thermopylae Science & Technology (the company where Clark worked for nearly nine years prior to moving to DigitalGlobe), to keep GEE “on life support.” This will allow users to continue to access it and the applications they built on it, while transitioning to ArcGIS Earth, Map of the World 3D on Cesium, or another 3D environment. “ArcGIS Earth will have the closest look, feel, and behavior to what Google Earth provides today,” says Russell.

In preparation for moving off of GEE, GVS is pursuing two different applications: a desktop installation, similar to the current public version of Google Earth, and a Web-based client. The former is aimed at users in disconnected environments, who need to be able to run a small portable globe that GVS develops and sends them. “We send portable globes all around the world with .5TB to 2TB of data (and sometimes more) to many of our disconnected users who would otherwise have no access to a geospatial environment for their operational and tactical planning needs,” says Russell. That, he adds, is another reason why GVS offers ArcGIS Earth as an install.
The Web-based client it is developing is based on Cesium and will provide access to NGA’s Map of the World environment, which integrates all GEOINT-related and multi-source content through twelve different data views. This option will not require users to install a client on their device, but does require a network connection. "They are both being built to have an advanced KML exposure capability in order to transition users smoothly off of Google Earth and into another realm," Russell says. "The Defense Information Systems Agency wants to ensure that future users stop developing KML and start developing more OCG-stringent data services. However, based on the number of KML services that have been developed and their scope and size, it would be unfair to have our user community re-write or re-accomplish all of those services they have already built into some new format."

While GVS’ primary focus in replacing GEE was to make sure that it met all of the requirements of its current users, the transition does offer NGA the opportunity to extend some capabilities. "Many of the advanced capabilities and exploitation capabilities are being developed by the exploit program office and a soon-to-be-awarded analytic service contract," Russell says. "Additionally, we are partnering with the National Reconnaissance Office to leverage some of what they have been able to develop in their open source version of Cesium, the Multi-Int Spatial and Temporal (MIST) Toolkit in 2D and 3D, to increase the capabilities we have available in Map of the World. A lot of what we are looking to leverage is more of the heavy analytical functions we don’t currently have within our visualization tools."

Early on in the GEE replacement effort, GVS also addressed the need for 4D visualization—that is, 3D plus the temporal perspective—to enable users to look at how objects or targets change or behave in relation to each other over time. With aircraft and satellites flying over specific targets or covering large swathes of the Earth, this time slider technology enables them to see where things were and what was happening on the globe at different points in space and time. “Temporal analysis has been in increasing demand from many of our user groups over the past year,” says Russell.

3D SPATIAL ANALYSIS AT PLANETARY SCALE

3D view has been a standard in industry for more than a decade now. Recent development efforts by Esri, VRICON, and others have demonstrated “an exciting amount of growth in the number of people who recognize the need for 3D,” says Clark, who had predicted this trend in the spring of 2015. These capabilities are coming to market as the deadline for deprecation of the GEE approaches. "I think that it is exciting to see,” he says. “It has raised awareness about 3D and its role in spatial.”

Recently, Clark points out, there has been an upsurge in interest and capabilities with regards to remote sensing and spatial analysis at planetary scale, including DigitalGlobe’s development of its Geospatial Big Data Analytics Platform (GBDX), the work of Rebecca Moore’s Earth Engine team at Google, and the rise of microsatellite companies, such as Planet Labs. They are “gaining answers and insights, not just pixels,” he says. “It is going to be interesting to see how that type of information fits into some of these new 3D tools. What does a 3D picture look like when we can start doing such things as monitoring and change detection over days, weeks, and months? Some fascinating things are coming with processing information at scale and then putting it in a 3D environment.”

DigitalGlobe is making all of the 90+ petabytes of data in its archives accessible in the cloud via its GBDX platform, enabling anyone to extract knowledge from them. "I wonder how capabilities
like ours will play in 3D GEE replacement capabilities,” says Clark. “Once there are a couple of 3D products out there, I think that people are going to want to do things with 3D that they were never able to even contemplate doing before.”

**IS SPATIAL SPECIAL?**

While geospatial is increasingly just another dimension of data, the real challenge has been to use it correctly, according to Hill. As an example, he cites the way we measure populations. “They are statistical estimates from the aggregation of people in administrative units, which don’t really adhere to predictable shapes and sizes in geographic space. They have different sizes, different relationships with their neighbors, and all these characteristics that make them challenging to analyze in reliable ways.” Previously, he points out, only GIS experts knew methods to deal with this challenge, but now data scientists increasingly have access to those tools, and GIS in business enterprises is getting closer to being a data science. “At the enterprise level, we are going to see more and more GIS practitioners doing more broad data science. And geospatial will be incorporated in everybody’s data science.”

DATA SCIENTISTS INCREASINGLY HAVE ACCESS TO THESE TOOLS, AND GIS IN BUSINESS ENTERPRISES IS GETTING CLOSER TO BEING A DATA SCIENCE.

– Andrew Hill, CartoDB

So far in this series we have featured ArcGIS Earth, VRICON, INdicio (by Galdos Systems Inc.), Skyline Globe and Terra Explorer (by Skyline Software Systems), Onix Networking Corp. (which integrates Skyline software into organizations’ IT systems), CartoDB, DigitalGlobe, and the NGA. In future articles, we will explore further the offerings of DigitalGlobe, including their newly launched Maps API, and continue to explore the constantly changing landscape of geospatial vendors, products, and large users and the percolating repercussions of Google’s decision to end support for GEE.

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**Matteo Luccio**, the company’s founder and president, has been writing about geospatial technologies for 16 years. His articles have been published in about 20 trade magazines and he has been editor of six of them.

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THE ADVENT OF MASS-PRODUCED, MINIATURE satellites is radically changing Earth observation by vastly increasing the imagery’s “refresh rate.” San Francisco-based Planet Labs is at the forefront of this upheaval, producing, launching, and operating hundreds of spacecraft. The company plans to launch more than 100 satellites and achieve daily coverage of the whole Earth this calendar year.

“As more and more satellites come online, first we will be producing a global basemap, then repeat coverage on a quarterly basis, then on a monthly basis, then on a weekly basis; then on a sub-weekly basis,” says Andrew Zolli, the company’s VP of Global Impact Initiatives. Yet, according to Robbie Schingler, the company’s Chief Strategy Officer and Co-Founder, the next major revolution in geospatial technologies will be on the ground, based on expanded capabilities to exploit that flood of data from space. I discussed the company’s mission, technology, and market strategy with Zolli and Schingler.
PLANET LABS’ MISSION

Zolli was first exposed to Planet Labs in the early stages of its development. With the help of a foundation, he recalls, the company convened a group of thought leaders in humanitarian, social, and ecological innovation to explore what its imagery might mean for the way we address global challenges. “It was immediately clear to all of us that the company’s data, tools, and platform could be an absolute game changer,” he says. “I was especially blown away by the potential to democratize access to this kind of imagery, to get people directly engaged in stewarding the planet.” (See Sidebar on Planet Labs’ commitment to addressing global challenges via “Open Regions” on page 24.)

Planet Lab’s mission is to image the whole Earth, every day, and make global change visible, accessible, and actionable. The company, Zolli explains, is at the forefront of three revolutions:

- a space renaissance, characterized by a new generation of space-oriented companies;
- a global sensing revolution, characterized by the deployment of vast arrays of sensors to detect change on the planet at scale; and
- a data and analytics revolution, which is making vast quantities of data available to be combined, analyzed, and turned into useful insight.

“Planet Labs participates in all three of these. We’re deploying the largest constellation of Earth-observing satellites in human history; when fully operational later this year, our constellation will capture the entire terrestrial surface of the Earth, every day, at a resolution of roughly 3m per pixel. Then we’re bringing that data to the Web via a platform and API, so that anyone can get access to it.”

Unlike traditional approaches to geospatial imaging, he says, his company is not a tasking-oriented service. “We are not pointing satellites, we are not turning them on for discreet periods of time when they are focused on a particular patch of Earth. Instead, Planet Labs is delivering a persistent monitoring mission—seeing everywhere, every day.”

This approach yields not only imagery of what the Earth looks like in its totality on a given day, but also evidence of unfolding changes in nearly real time, and indicators of coming change. “That has enormous economic value, as you might imagine,” says Zolli. “At the same time, we’re also able to see the spread of droughts, the variation in agricultural yields, and the roads that are built before illegal deforestation occurs. In the right hands, these indicators can be used to save our fragile ecosystems, improve global food security, and save lives.”

SPATIAL RESOLUTION VS. TEMPORAL RESOLUTION

The temporal resolution of Planet Labs’ imagery will be daily and its coverage is global. Therefore, Zolli points out, it is not sufficient to simply compare Planet Labs’ 3-meter/pixel imagery to higher spatial resolution imagery and ask which one is better. “Each has its applications, and, interestingly, they might find their best use together.” A daily refresh rate, for example, is especially good for monitoring for change, while a higher-resolution, task-based sensor can yield a very useful image if you know where to look. Originally indicating the number of times in a second that a display hardware updates its buffer, “refresh rate” is increasingly also used to refer to the time between two images of the same geographic extent taken by the same sensor system. “Planet Labs’ imagery is especially good for detecting high-level change and figuring out where to look,” says Zolli. “The two can work together.”

In other cases, Planet Labs’ “deep stack” of imagery is essential, because it allows users to see what a place looked like just before a radical change, such as a natural disaster, Zolli points out. In most cases, the company is likely to have the most recent pre-disaster imagery for any given place on the planet, which is hugely important in understanding what buildings have been knocked down. Likewise, in the case of forest fires, a “deep stack” of imagery helps monitor a fire’s progress. Therefore, the temporal resolution of the company’s imagery is at least as valuable as its spatial resolution.

BUSINESS MODEL AND ACCESS TO THE DATA: THE PLANET PLATFORM

Planet Labs sells its data to private companies, public institutions, national and local government agencies, and international institutions. “Many organizations in such areas as precision agriculture, forest monitoring, or insurance have a strong interest in our data,” says Zolli. Planet Labs is also introducing a cloud-based platform to provide direct access to its imagery. “Soon, you’ll also be able to upload your own datasets and run your own analytics on top of our platform,” he says.

The company sees this cloud-based platform as transformational. Historically, Zolli explains, the

![Figure 1](image-url)

*In the weeks following the Bento Rodrigues Dam failure in Brazil, which was Nov. 15, 2015, the Rio Doce has carried water contaminated with iron-mining waste 300 miles to its mouth in the Atlantic Ocean. Image: Planet Labs, captured November 29, 2015.*
Planet Labs’ global coverage and very high imagery refresh rate enable them to see change and how it happens on a monthly, weekly, and even daily basis. The company aims to make this resource, once the provenance of the very few, as widely available as possible. To help realize this vision, the company has launched an initiative it calls Open Regions.

“We’re picking areas of the world that contain a lot of varied geography, with complex ecological, social and economic challenges, and making them available to everyone, for free, under an open-source license,” says Andrew Zolli, the company’s Vice President of Global Impact Initiatives. “We’ve started in California, and already, that’s attracted all kinds of organizations and researchers to our platform. Last September, at

― Robbie Schingler
and Commitment of $60M

humanitarian and social impact organizations that could most benefit from this kind of data were the least likely to be able to access it due to the cost and the technical proficiency it required. A cloud-based platform, however, requires neither an in-house geospatial team nor large data purchases. “We are making this available for the masses and will bring many millions more people and organizations into the user community,” he says.

At the same time, advanced analytics companies are beginning to use the company’s data in new ways. For instance, a machine-learning and computer vision company called Descartes Labs used them to reveal an error in U.S. government forecasts of U.S. corn production, and another company is using them to study China’s economic productivity. “This ability to produce new kinds of indicators is going to have a huge impact on the way we solve problems in the future,” Zolli predicts. With regard to such problems as public health, climate adaptation, poverty alleviation, and urban resilience, he explains, a reliable signal is a prerequisite for effective action.

Last year, Planet Labs acquired BlackBridge, which operated its own constellation of satellites, commonly called RapidEye. It then integrated BlackBridge’s repository of Earth observation data into its platform, which also contains datasets from Landsat and from Planet Labs’ Dove constellation. “In addition to this,” says Zolli, “BlackBridge brought real depth of experience in certain markets. For instance, they were a significant player in the REDD and REDD+ markets, in which geospatial data is used to reduce deforestation and forest degradation.”

IMAGERY FOR AGRICULTURE

While about 90 percent of farmed areas in the United States are covered by a federal crop insurance program, in many developing countries, two-thirds of the food is grown by so-called “small-holder” farmers. The United Nations, we made a public announcement that we’ll initially be putting $60 million worth of data into Open Regions to spur inclusive sustainable development.”

As a commercial enterprise, Planet Labs has to take into account the opportunity costs associated with giving data away. However, it was founded with a goal of encouraging planetary stewardship and is always looking for a business model to support its mission, rather than one that only maximizes its returns. “Our goal is not just to grow the market, but also to ensure that price doesn’t get in the way of transformational change,” says Zolli.

Planet Labs’ Ambassadors program incubates groups of research scientists and others who are engaged in R&D on top of its platform, such as advanced forest-monitoring techniques. The company is also conducting a strategic review of the world of disaster and emergency response and is exploring new ways to ensure that the right people have the right information at the right time to save as many lives and as much property as possible.

Planet Labs also focuses on slower-moving humanitarian crises. For example, in the Syrian crisis, it has monitored the growth and movement of difficult-to-access refugee camps. “We can see the daily growth in the number of tents in the desert, which is a pretty good proxy for how many people are there,” says Zolli. “That kind of passive surveillance is going to be extremely important in ensuring that limited humanitarian resources go to the right places.”
They work at near subsistence levels on informal plots of land that are often just a fraction of an acre. This makes it impossible to provide them crop insurance, Zolli explains, because it’s hard to see what’s happening on the ground for them. “While their labor costs are very low, their exposure to such things as climate change is very high. If there is one significant drought event, they could easily be pushed off of their land, which would be a calamity not just for them but also for the many people that they feed.” Planet Labs’ satellites, in conjunction with small ground weather stations, could play an important part in making crop insurance feasible at scale in vast areas of the world where it is not yet feasible, Zolli says.

WEATHER DATA

Weather has a huge impact on many facets of society, especially due to climate change. Traditional weather satellites are very large, carry up to a dozen sensors, weigh thousands of kilograms, take up to ten years to build, and are very expensive. Planet Labs has proven the ability to build very capable Earth imaging sensors that are two orders of magnitude smaller (this drastically reduces the total mission cost, which is mostly due to getting the satellite into space) and autonomously operate them, says Schingler. “You don’t necessarily need to create a spacecraft that looks like a Christmas tree. You can actually throw the individual ornaments up themselves.”

Launching much cheaper, single-sensor weather satellites that can be mass produced quickly would provide a higher temporal capability than the current generation of satellites, Schingler points out. “I think that there is an opportunity for other companies to do for the weather market what we have done for electro-optical and near-infrared capabilities for Earth observation. That torrent of data will then allow people to make better decisions, based on the changing weather around them.”

The commercial weather market today is analogous to that of remote sensing 20 years ago, Schingler argues: people are used to getting weather data for free from a few major governments around the world. Therefore, commercial weather companies have to both create and serve a new market.

GETTING IMAGERY DOWN TO EARTH

Planet Labs’ business model and operational set-up do not include live streaming of data from space. The company’s satellites operate in a store-and-forward manner: they are constantly capturing and compressing data, then transmitting them whenever they are over ground stations. These stations, in turn, send the data to the company’s cloud servers, which decompress them, calibrate them, orthorectify them, and make them available to end users via a Web-based API.

Streaming data from space can be done in several ways. One is to transmit them directly down as they are captured. However, that requires ground stations everywhere. An alternative is to beam the data up to a telecomm satellite that then transmits them down to
the ground. However, that is very expensive, because it requires having many satellites in your network. “A third architecture,” Schingler explains, “is to have your satellites talk to one another, because odds are that you will have a spacecraft that is looking at a ground station.”

Current real-time feeds from space include some from satellites in a geostationary orbit, such as weather satellites. They send updates every 15 minutes but at very coarse resolution, because they are so far away. The International Space Station can stream data from its cameras because it is always connected to NASA’s telecomm satellite, the Tracking and Data Relay Satellite L (TDRS-L), which then transmits this near real-time feed of the planet down to ground stations.

**THE NEXT BIG THING**

“The next big thing for geospatial,” says Schingler, “is in multi-source data fusion capability on Web-based platforms, using streaming information feeds, and bringing to bear against geospatial data a variety of computer vision and machine vision learning algorithms that have primarily been developed by large IT companies over the last half decade.” That, he argues, will increase by orders of magnitude the number of users who can consume geospatial data and information services derived from this information feed—including many users of business intelligence and decision support tools who are not GIS experts. “The next major revolution will be on the ground, with data exploitation and the ability to build sustainable businesses on top of the unique information feed that comes from space and to match it up with data collected on the ground.”

Because Planet Labs’ satellites are collecting imagery continuously and will soon be refreshing their complete Earth coverage daily, users no longer need to be experts about the satellites’ capabilities. His company, Schingler says, wants to give people the ability to see global change and access that information via their mobile platforms. “Once that market grows a lot, then we’ll see again an explosion of new sensors in space to meet users’ needs.”

Zolli believes that in the future we are going to see countless new applications for his Earth observation data. For example, the framework agreement on climate change signed last December at the UN Global Climate Summit in Paris calls for putting a price on carbon, which requires functioning carbon markets. “We believe Planet Labs’ data is going to be an important tool for underwriting the success of those carbon markets,” he says. “We are building a platform on which there will be many, many applications, including some that we ourselves cannot foresee.”
Slowly, the fruits of this work have seeded the commercial world, sprouted and intertwined with outside interests to create a rapidly changing environment that will sweep up the GEOINT community. Today, we see an unprecedented democratization of geospatial information underpinned by an invisible layer of spatial and temporal information linking people, places and activities around the world. The reality is that, if we look deeply, we see GEOINT everywhere, used by everyone throughout our day—we just don’t realize it until we take a step back. Of course, the governments of the world use geospatial information, but so do our soccer moms, our marketers, our farmers, and our children.

This phenomenon is due to three underlying and enabling trends:

- An increasingly data-centric environment,
- The creation and mass proliferation of advanced analytics, and
- The ease of access and intuitive visibility anytime, anywhere.

The continued convergence of these trends has caused a sudden and radical shift to our community. Welcome to the GEOINT Revolution.
A DATA-CENTRIC ENVIRONMENT

In the last year, we have created more data than previously existed in all of history and over the last decade the total size of the data universe has doubled every two years. The fact is that today we live in a data-centric environment; data is all around us and its tremendous influence on our lives will continue to grow in significance. Much of this data is open source and available at our fingertips, through a few clicks via the web and our phones. Each person, activity, and process generates a data trail of geospatial information in many forms and structures creating what I have previously called a "Data Bazaar." The choices that exist in the Data Bazaar come in multiple forms, flavors, types, colors, and sizes. The exploration of the choices often creates more questions that then lead to more data. The community must determine how to adjust to this new data-driven environment.

As an example, only a handful of commercial remote sensing companies and the LANDSAT constellation provided access to geospatial data—almost exclusively imagery products. In the last decade, commercial investment has doubled the number of players in that market and proposed investment could double it again in only the next five years. The potential supply of imagery product could create constant and continuous collection of 100% of the globe.

Despite the potential flux of data coming from imaging satellites, another dynamic will make the environment more data-centric and propel the GEOINT Revolution. The majority of geospatial data today comes from our mobile phones and tablets, smart televisions, laptops and watches, multiple global navigation systems like GPS and Galileo, and even our automobiles and social media. Additionally, the Internet of Things, the spread of interconnected intelligence infrastructure, will generate the momentum of the Revolution as it is estimated that the size of the digital universe will grow 10X every two years rather than its current rate of 2X.

ADVANCED ANALYTICS

Acknowledgement of the data-centric environment, with more data than our past tools could handle, has caused more focus on advancing our analytical world and automating as much of the process as is possible. Without it we would all drown in the data deluge. However, at this very moment around the world, automated analytical tools have been developed and are hard at work consuming this data to predict your next move through the use of complex models that can analyze the wider variety of more complex datasets.

The big advances in analytics represent their own sets of convergences involving hardware computing and storage improvements, increased algorithm sophistication, and maturity in predictive methods and machine learning. Yet the biggest advance has been in tailoring these concepts to address identifiable applications and solve specific problems. Beyond the obvious impact to the national security, advances in analytics are transforming entire sectors like transportation, energy, health care, marketing and sales, and finance—all of which have a significant geospatial component.

Adding to the democratization of geospatial data, advanced analytics mixed with the spread of intelligent infrastructure does more than create more data. Whether mobile or static, it is centralizing and automating decision making at a local level in near real-time to provide customized responses to external and internal environments. This dynamic analysis across time and space is the essence of the GEOINT Revolution and continued advances are necessary to fuel it.
ACCESS AND VISUALIZATION

While the Data Bazaar has driven demand for advances in analytics, these advances would have little import or impact without access to and visualization of geospatial information. Several innovations have facilitated the Revolution in this area.

Despite its esoteric nature, common data standards and open architecture development allow a myriad of sources and systems to work together. This has eliminated proprietary stovepipes, establishing common foundations for interconnect and communication and enabling an unprecedented level of integration of data and knowledge. Platform-agnostic solutions have produced an environment where users can access and visualize geo-tagged information for their own specific use cases. Common mobile and smartphone applications leveraging geospatial information flood the consumer marketplace and add to the invisible layer of spatial and temporal data referenced earlier.

The proliferation of communications infrastructure has propelled today’s access to geospatial data. Today, cellular and Wi-Fi networks have become universally available and, by many definitions, a public good, creating billions of, often unwitting, users of geospatial information. In the immediate future, commercial satellite investment will offer ubiquitous internet and global connectivity that will significantly expand access to and collection of geospatial data. Examples include current providers of high throughput communications like Intelsat and SES as well as future constellations proposed by OneWeb and O3B (Other Three Billion, named after the number of users who do not currently have internet access).

In a seemingly unrelated market, Graphic Processing Units (GPUs) from the gaming industry have become an important part of multimedia computing and graphics processing. Advances in this arena have changed the user experience with respect to computing power and visualization. Spatial and temporal data, which once seemed cartoonish, now provide the user with authentic and life-like 2- and 3-D experiences. When integrated with geospatial data, it has not only significantly advanced the visualization of the data, but it has greatly enhanced the value and breadth of applications causing a dramatic shift in the number and types of geospatial products available on the market.

Closely linked to advancements in GPUs, augmented and virtual reality advancements have begun to make their mark on the GEOINT community. These markets have picked up remarkable momentum over the last five years moving from pedestrian activities to an estimated $5B-plus market in 2016. The integration of geospatial data into these systems will transform a number of applications from the common training and education experience to the travel and recreation industries. We will move beyond 3-D to the 4-D experience.

Advancements in technology can bring about dramatic change, but rarely can it start a revolution. Revolutions always involve cultural change and impact real people. They come from the convergence of multiple trends that collide to create drastic shifts in culture. Today the GEOINT community, made of real people, stands at the center of several trends that have already shifted the ground beneath its feet. It is unlikely that this disruption will be temporary or short lived. The GEOINT Revolution is here. What will you do to embrace it?
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