APOGEO SPATIAL

ELEVATING GLOBAL AWARENESS

A New Island Emerges in the South Pacific: Tonga Island
p. 36

Ocean Shoreline Dataset Coming from Airbus
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New Plan: An Economy for Humanity
p. 30

Google Earth Enterprise Now OPEN SOURCE

THE INSIDE STORY p. 14

"Global sustainability is a property of the Earth's Life Support System, which can only be attained if economy has the dual purpose of safeguarding the planet while ensuring the well-being of human communities."

– Hans-Peter Plag, Mitigation & Adaptation Research Institute, Old Dominion University p. 30

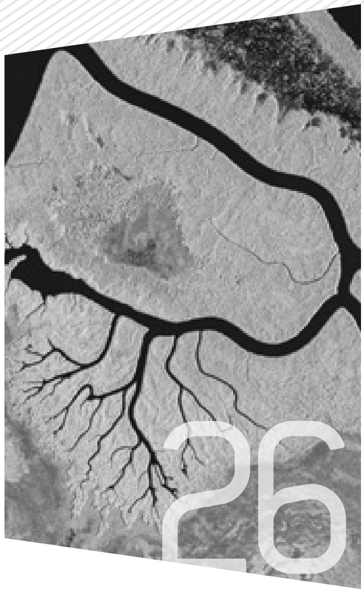
"We want to extend GEE (as open source) to be able to handle large 3D datasets... such as data coming from self-driving cars, UAVs, and LiDAR."

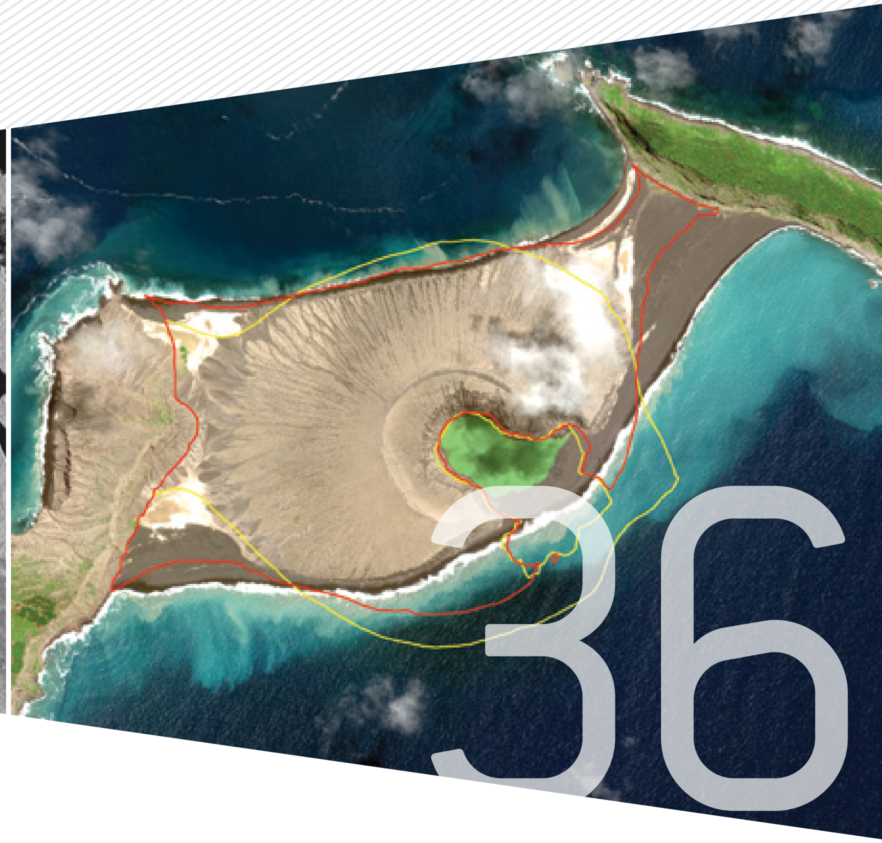
– David Moore, Navagis p. 14

FORMERLY Imaging Notes

[Spring 2017 / Vol. 32 / No. 2]

DEM of South Africa, with Cape Columbine in the top portion of image, courtesy DLR 2016 and Airbus DS Geo GmbH 2016





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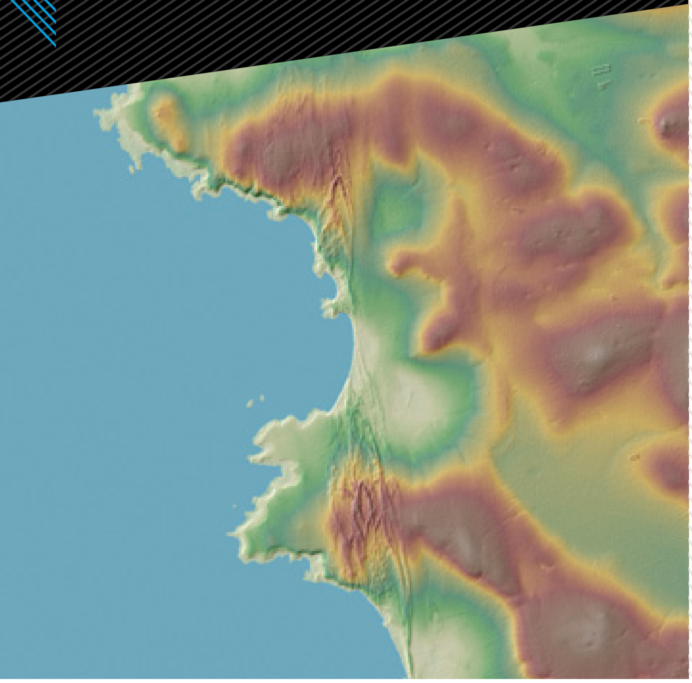
Columns

Special Section & Series

by Matteo Luccio, Contributor, Pale Blue Dot LLC

Features

COVER IMAGE



Cape Columbine, Saldanha Bay

SOUTH AFRICA

CAPE COLUMBINE IS LOCATED in Saldanha Bay, a natural harbor on the southwest coast of South Africa. A famous lighthouse and nature preserve are located there, about 110 km (70 miles) north of Cape Town, in the Westkap Province.

This image is from the WorldDEM global elevation dataset, which covers regions beyond 60° North and South without any missing areas, even in the heavily clouded Equatorial belt. Its main features are pole-to-pole coverage without any breaklines at regional or national borders, and no heterogeneities caused by differing measurement procedures or data collection campaigns staggered in time.

WorldDEM is based on data acquired by the high-resolution radar satellites TerraSAR-X and TanDEM-X, which collected data from December 2010 to 2013. The satellites covered more complex terrain areas with third and fourth acquisition campaigns.

Image courtesy of DLR and Airbus DS Geo GmbH 2016. ΛO

APOGEO SPATIAL

Formerly Imaging NOTES

[Spring 2017 / Vol. 32 / No. 2]

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- **CHRIS POWELL,** CTO, **NT Concepts**
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1. The Demise of Google Earth Enterprise

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- **MATT IRWIN,** Business & Government, **Mapbox**

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5. Geospatial Solutions from PIXIA, Luciad, & BAE Systems

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By Matteo Luccio
Pale Blue Dot LLC
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Apogeo Advisors: Consultants for a Rapidly Changing Space Sector

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

DEAR READER,

This issue marks 14 years that my company has owned *Apogeo Spatial*, and it has enabled me to see the macro view of the satellite and space sectors, and to acquire a wide horizontal knowledge base that is quite rare. I have interviewed and met with executives from all areas of our ecosystem. I bring people together; I connect the dots and see the patterns.

Based on this experience, I am thrilled to launch Apogeo Advisors, a strategy and marketing firm bringing a comprehensive understanding of the ecosystem, with other members of our team bringing deep vertical knowledge, as well. We help companies that are seeking to reach commercial markets after working with government agencies, that want to create partnerships with international organizations, and that need to translate technical jargon into understandable language for marketing and sales, as examples.

Members of our team include Jurgen Mantzke, who was my original designer for this publication in 2003, then called *Imaging Notes*. He was instrumental in creating the sophisticated design that lives on today. He is now an expert in User Experience (UX/UI) design.

Matteo Luccio is a prolific and talented geospatial writer; almost every issue of *Apogeo Spatial,* and other publications include his work.

Elliot Pulham was most recently CEO of The Space Foundation. He won the Silver Anvil Award for leading the team that rebuilt Congressional and public support for the International Space Station program. An advisor to three Chiefs of Staff of the U.S. Air Force, he was awarded the U.S. Air Force Distinguished Public Service Medal, an honor he shares with Dr. Neil de Grasse Tyson.

Paul E. Smith is an expert in location-based technologies and geo-content products. He was Chief Commercial Officer at C3 Technologies (acquired by Apple), whose 3D photo-realistic maps broke new ground in online mapping, and Chief Strategy Officer at earthmine Inc. (acquired by Nokia/HERE), an innovator in street-level panoramic imagery. He was co-founder and Chief Operating Officer at GlobeXplorer, a leader in cloud-based, Earth imagery Web services (acquired by DigitalGlobe).

My macro view is like the Overview Effect: it has helped me see things more clearly – trends, positioning of different companies, how the ecosystem fits together. The overview effect is an inspiring change in perception that brings an awareness that everything in the universe is connected.

What I see happening in our industry is inspirational too. The NewSpace companies (SpaceX, Blue Origin...) are pushing the envelope on what's possible, with extremely bold visions. They understand the value of marketing, which is one reason they are getting so much attention – from investors, from the media (such as *The Atlantic, The Economist, Esquire…*), and from the public.

Marketing is complex. It should be different for every company. For example, not all companies should invest in advertising. Whether it makes sense for a company to do so, and whether it should be branding versus lead-generation/digital depends on many things, such as how mature the company is, whether they are launching new products or services, etc.

A strong brand is the backbone of a product or company. Building a brand is complex, and can include advertising. While advertising spending is under increasing pressure to show a financial return on investment, creating a solid brand is more subtle than lead generation and "clicks" online. The influence of branding is powerful; the value of branding is priceless.

While I am announcing Apogeo Advisors here, rest assured that the publication will continue to provide in-depth articles that are objective and relevant to your business. We are still committed to editorial integrity. *Apogeo Spatial* delivers your branding message into the hands of the right executives. Email me to talk.

Sincerely, Myrna

ON THE EDGE

Changing the Story: The Planetary Physiology

Prof. Hans-Peter Plag, PhD

Mitigation and Adaptation Research Institute

Old Dominion University

Norfolk, Va.

www.mari-odu.org

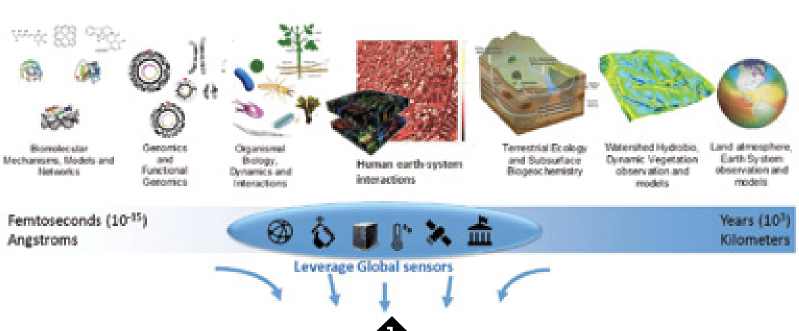
IT SURPRISES ME AGAIN AND AGAIN HOW much we know, or could know, and how much we choose not to know. Behavioral economy and cognitive psychology have taught us much about human biases and how they impact the reflections we have of the world and the decisions we make.

The discussion about climate change is a good example of our ability not to see the obvious and to reason against it. In an attempt to explain the ice ages, Svante Arrhenius in 1896 published a paper that explains the basics of how, and how much, atmospheric Greenhouse gases impact global temperature.[1] The data collected since then has consistently confirmed what he derived more than 120 years ago. In 1906, he suggested that human emissions of carbon dioxide could be a means to keep the planet from entering a new ice age.[2] The scientific knowledge developed since then has provided a deep understanding of the fragility of the stable homeostasis humanity had the pleasure to experience during the Holocene, the last geological epoch that started about 11,700 years ago.

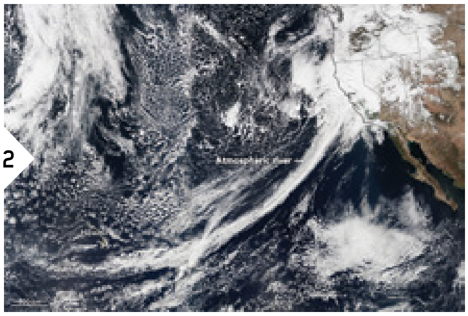
Instead of eagerly listening to the experts and asking them for guidance of how we can prolong this great time of climate stability for the benefit of us and those that come after us, too many of us engage in denial and ignorance of the knowledge readily available for short-term economic benefits with little consideration for the harm and injustice this is causing. The discussion about climate change, its extent and its causes has developed into an unreasonable dialog, a confrontation where the parts keep exchanging their positions without reasoning.

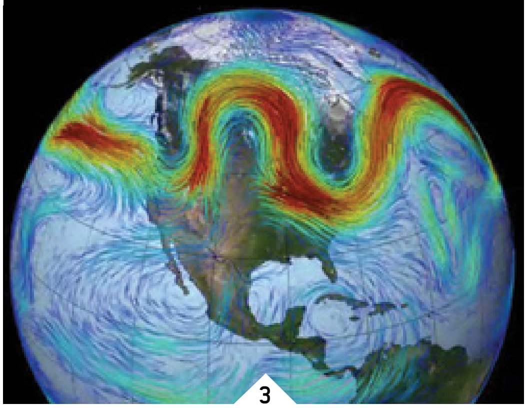
At the Conference on the Future of Engineering Software (COFES)[3] in Scottsdale, Arizona on April 6-8, 2017, I engaged in such an unreasonable dialog. I participated in COFES as a member of the "Earth Energy Monitoring System" (E2MS) working group.[4] This group originates from the CTO Design Challenge addressed at the Future in Review (FIRE) conference held in September 2016 in Park City, Utah.[5] The topic of the 2016 FIRE was "flows" – flows in all forms and of all different elements. The CTO Design Challenge focused on the conceptual design of a monitoring system for the flow of energy in all its forms through the Earth system. Looking at the world in terms of flows changes the story from arguing about the symptoms and phenomena to a dialog about the processes and causes. By changing the story, the focus of our societal discourse, we can change the future.

In the Technology Suite Briefings at COFES, new initiatives can be presented to, and discussed with, a small highly interested audience in a somewhat unusual setting. In our briefing on the E2MS, it was my task to illustrate the challenge humanity is facing and to explain how the E2MS would provide information helpful to decision makers. In the last 250 years, we have increasingly accelerated



▶ FIGURE 1. Energy flows in the earth system cover a wide range of spatial and temporal scales. Knowing the flow of energy is key to understanding the dynamics of the evolving, non-stationary complex system and its emerging properties. Leveraging the abundant data from rapidly growing networks of sensors from the traditional Earth observation system to crowd-sourcing and the coming Internet of Things, the E2MS aims at a detailed picture of all flows in the Earth system. Source: E2MS.





flows in the Earth system, and these accelerated flows have changed the overall balance – or imbalance – in the Earth system. During this period, humanity increasingly had access to energy and technologies that could be used to make large-scale change to our planet.

Since about 1950, when we achieved easy access to nearly unlimited energy, our species was able to modify flows in the Nitrogen and Phosphorous cycles and thus could produce the food for the rapidly growing population. We change flows and storage in the water cycle to support the production of food and more energy and to provide access to water for other purposes. The flow of humans increased with millions on the move, both voluntarily for business or pleasure, or involuntarily as migrants fleeing unlivable conditions. The flow of material resources into products and from there into waste accelerated to satisfy the greed of a growth-addicted economy. The flow of wealth escalated with more and more of it concentrated in the hands for fewer and fewer. The flow of data from sensors is exponentially increasing without necessarily turning into knowledge and wisdom. Information flows inflated both with and without the consent of the owners.

We changed land use by taking away forests and pastures to make room for agriculture, sprawling human settlements and extensive infrastructure. In 1700, a mere 650 million people used on the order of 1% of the land surface. Today, close to 7.5 billion people occupy on the order of 50% of the land surface. On the way, we changed the carbon cycle and by adding carbon dioxide to the atmosphere and oceans, we changed the energy flow and amplified the imbalance of the energy that comes from the sun and is radiated back into space.

Over Earth's history, this imbalance is very small, probably less than 10^{-9}, but just enough to build considerable energy reserves in form of fossil fuels over hundred of millions of years. Considering the additional energy that is currently stored in the atmosphere and oceans as part of global warming, the imbalance is now closer to 10^{-3}, a million or more times larger than on average during millions of years. This change in the flow of energy is changing the characteristics of the planetary system.

We also changed the biosphere and how the biosphere is utilizing solar energy. We eliminated the 30-60 million buffalos that populated North America when the first migrants from Europe arrived. Each of them has a metabolic rate of more than 400 W, summing up to a total of 12.5-25 GigaWatt (GW). The buffalos used this amount of basically solar energy to process a huge amount of biotic material and to enrich their environment with the remains. In Africa, the 20 million elephants that once roamed this continent used on the order of 40 GW to do the same there. We have removed these "ecosystem services" almost completely.

Similarly, we have changed the energy flow in many other parts of the Earth's life-support system. Importantly, we have added our extended metabolic rate of almost 3,000 W per person on global average into the system's energy flow. In order to understand how these changed flows change the characteristics of the system, it is mandatory to focus on flows, measure flows, and to have an E2MS.

In our first briefing at COFES, we presented our initiative to a very observant group eager to hear what E2MS might contribute. During the Design and Sustainability (DAS) Symposium the previous day, there was agreement that we as a global society are not in good shape and need to make significant changes to face the economic, social and environmental challenges and to avoid potential looming disasters.

Like doctors who want to improve the health of a patient, decision makers who want to address these challenges need up-to-date and comprehensive information about the degrading Earth's life-support system. This was well understood by our audience, and the idea of developing an E2MS was well received. It was acknowledged that

▲ FIGURE 2.
In January 2017, an atmospheric river brought a flow of water to the drought-stricken Southwest of the U.S., causing problems with a sudden overload of water. Source: NASA.

▲ FIGURE 3.
The strength of the jet stream has an important impact on weather and climate, particularly on the northern hemisphere. The rapid warming in the Arctic could significantly change the atmospheric dynamics and weaken the jet stream with severe impacts on weather extremes. Source: Washington Post, "One of the most troubling ideas about climate change just found new evidence in its favor," March 27, 2017.

4

▲ FIGURE 4. According to the U.N. Refugee Agency, an estimated 65 million people are currently displaced and many of them are moving along major flow lines between continents.

changing the story and talking about the physiology of the planetary life-support system and the flows between us and this system could provide a basis for a reasonable dialog about our future and what we want this future to be. It was also realized that we have a huge amount of data that could be used to extract information about flows with a system like the E2MS.

The afternoon briefing session turned out very different. In all the material we were presenting, one person only heard one thing: "climate change," and he forcefully tried to negate every statement we made. He reproduced the well-known false arguments of NOAA having manipulated data, of the effect of Greenhouse gas on global temperature not being proven, of climate having changed always, and he went so far as to claim that Jupiter is warming over the last 20 years without anyone driving a car there. His antipodal attitude was actually beneficial because in the end, the audience understood our reasoning about the changing flows and saw the importance in our new story even better than in the morning, when nobody challenged our message.

Behavioral economics tells us how we make decisions and how our cognitive biases impact these decisions, but it doesn't answer the question why humans are the only species to develop reason as one of our cognitive senses. Reading Mercier and Sperber's new book on "The Engima of Reason"[6] brings us closer to an answer to this question of fundamental importance. They argue that reason was not developed and is not geared for solitary use with the goal to arrive at better beliefs and decisions on our own. It rather helps us to justify our beliefs, positions, and actions to other members of our communities, to convince them with argumentation, and to evaluate the arguments of others in an open dialog. Reason gave us an advantage as social beings and allowed us to have deliberations about the future we want to create together.

It hurts to see that in our modern society we seem to forget what reason was meant to be. Decisions are no longer made by communities after careful reasoning about the impacts these decisions might have on our common future. Like the climate change denier at our briefing, who had no interest in considering our reasoning, many of our leading decision makers up to the highest level are not interested in careful reasoning about the future we want and how to get there but rather make decisions for the benefit of short-term effects, including their rating on whatever rating system they are addicted to.

"Sense is the song you sing out into the world, and the song the world sings back to you." In Ari Berk's and Loren Long's book, "Nightsong,"[7] the bat-mother of Chiro uses these words to send him for the first time alone out into the fearful dark of the night, and she tells Chiro to use the "good sense" to find his way through the dark and back home. Bats use their unique "good sense" of ultrasound to cope with their specific conditions. Humans have reason as what could be our "good sense." But it is not enough to sing our song into the world, no matter how well reasoned; we also need to listen to the song the world sings back to us. "Listening" to the flows may be what is key to understanding the world. ∧♂

Endnotes:

1. Arrhenius, S., 1896. On the influence of carbonic acid in the air upon the temperature of the ground. *Philosophical Magazine and Journal of Science*, Series 5, Volume 41, pages 237-276.
2. His 1906 book on "Vaerldanas utveckling" was published in English in 1908 under the title *Worlds in the Making*.
3. http://www.cofes.com
4. http://www.e2ms.org
5. https://www.futureinreview.com
6. Mercier, H. and D. Sperber, 2017. *The Enigma of Reason*. Harvard University Press, Cambridge.
7. Berk, A., L. Long, 2012. *Nightsong*. Simon and Schuster, New York.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THE INSIDE STORY:

Google Earth Enterprise Goes Open Source

With Key Partners NT Concepts, Navagis, and Thermopylae Sciences + Technology

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

On March 20, 2015, Google deprecated Google Earth Enterprise (GEE), which had contributed greatly to the market for geospatial "Digital Earth" products for large organizations, and announced that it would stop supporting it on March 22, 2017. The company had previously announced that it would discontinue support for the Google Earth API and the Google Maps Engine, while it continued to support and promote Google Earth Engine. GEE allows organizations to store and process terabytes of imagery, terrain, and vector data on their own servers, and publish maps securely for their users to view using Google Earth desktop or mobile apps, or through their own applications using the Google Maps API.

Some thought that GEE would quickly fade away after Google stopped supporting it and its users would switch to alternative platforms that are already on the market, or build new ones. However, GEE had become essential for many of its users, including U.S. and foreign military and intelligence agencies, which did not see many viable alternatives, given their investments into the product, and the amount of work it would take to make the change. Therefore, at the beginning of 2017, Google began to prepare to open source GEE and to turn over maintenance and support of the product to three of its partner companies: NT Concepts, Thermopylae Sciences + Technology, and Navagis. See www.opengee.org.

Editor's Note:
Details on GEE as Open Source are at www.opengee.org. See also our series on options to replace Google Earth Enterprise, the final installment of which appears on page 20.

On March 23, Google published to a GitHub repository, under the Apache 2 license, three independent components within the Earth Enterprise baseline, for a total of 470,000 lines of code:

- its fusion server, which ingests the data to prepare the globes or the 2D maps
- its Earth server, which serves up the data, and
- its portable server, which allows users to import data and move it around on a laptop or on an Android or iOS device.

Google did *not* open source its GEE client, which enables users to consume the globe data in 3D, its Google Maps JavaScript API V3, which enables them to do so in 2D, nor its Google Earth API.

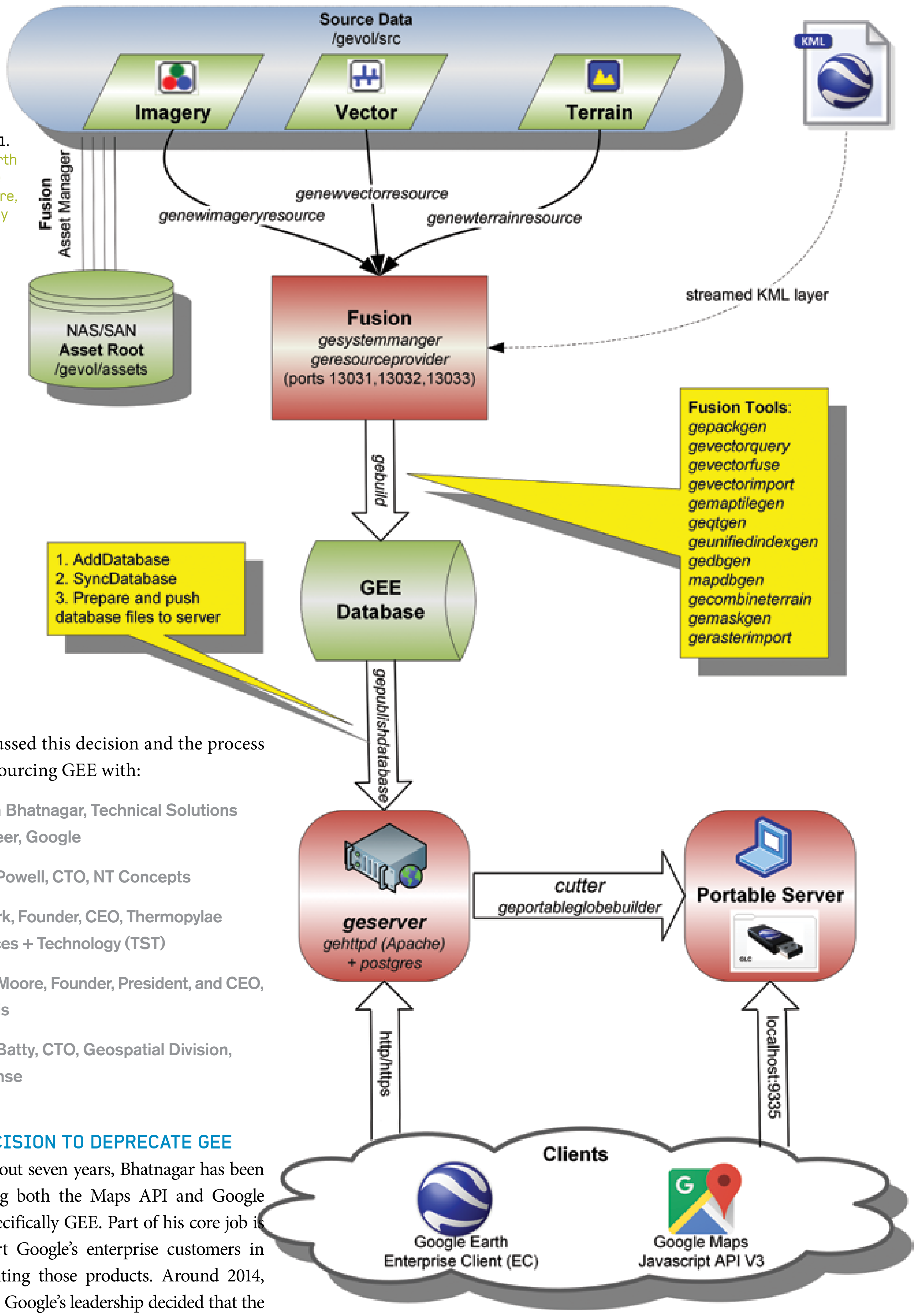


FIGURE 1. Google Earth Enterprise architecture, provided by Google

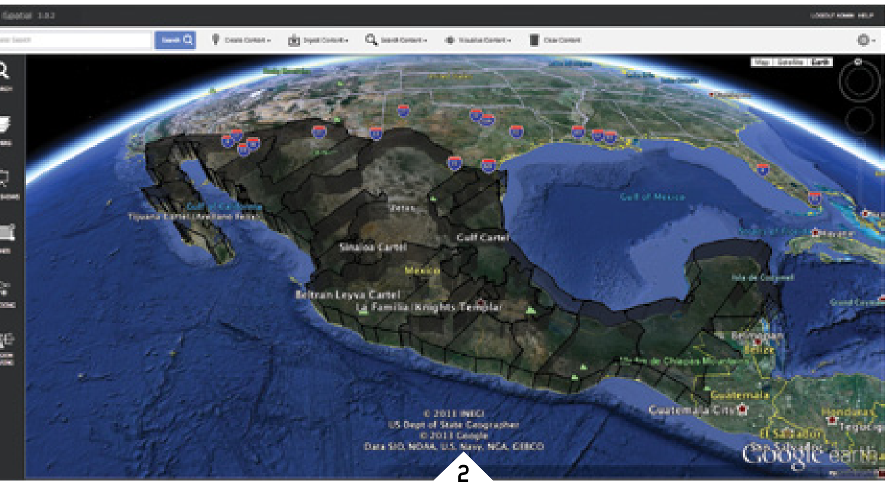
1

I discussed this decision and the process of open sourcing GEE with:

- Avnish Bhatnagar, Technical Solutions Engineer, Google
- Chris Powell, CTO, NT Concepts
- AJ Clark, Founder, CEO, Thermopylae Sciences + Technology (TST)
- David Moore, Founder, President, and CEO, Navagis
- Peter Batty, CTO, Geospatial Division, Ubisense

THE DECISION TO DEPRECATE GEE

For about seven years, Bhatnagar has been supporting both the Maps API and Google Earth, specifically GEE. Part of his core job is to support Google's enterprise customers in implementing those products. Around 2014, he recalls, Google's leadership decided that the



▲ FIGURE 2. Data overlaid on Google Earth displayed in 3D in iSpatial shows comparative crime rates across Mexico for the U.S. Southern Command, courtesy of Thermopylae Sciences & Technology

company should focus more on delivering rich location content via its APIs, while also enabling its customers to take full advantage of the Google Cloud platform.

"GEE has always been a very niche product, focused on a very important user base, but percentage-wise, a very small one," says Bhatnagar. GEE's adoption rate was much, much lower than what Google likes to see for its products. "So, they looked at this core business and decided that it was time to deprecate it."

Bhatnagar proposed open sourcing GEE. Initially, there were some internal concerns about how this might affect patents and benefit competitors. However, he says, the more the product teams, engineers, and everyone else involved discussed the proposal, the more they thought that it was the right thing to do for Google's customers.

In particular, Google recognized that GEE's customers were not its ordinary customers. "We are talking about the three-letter agencies within the U.S. government, as well as the Japanese Ministry of Defense, the Israeli Prime Minister's office, the British GCHQ, and so on," says Bhatnagar. "It's almost an invisible user base. Most of the time, we have full visibility of who is using our products, because they reach out to Google, so we can collect all kinds of data and logs and we know who is doing what, but with GEE we never had a good finger on how big our user base was. Hearing from our partners, it is a lot bigger than we ever expected it to be."

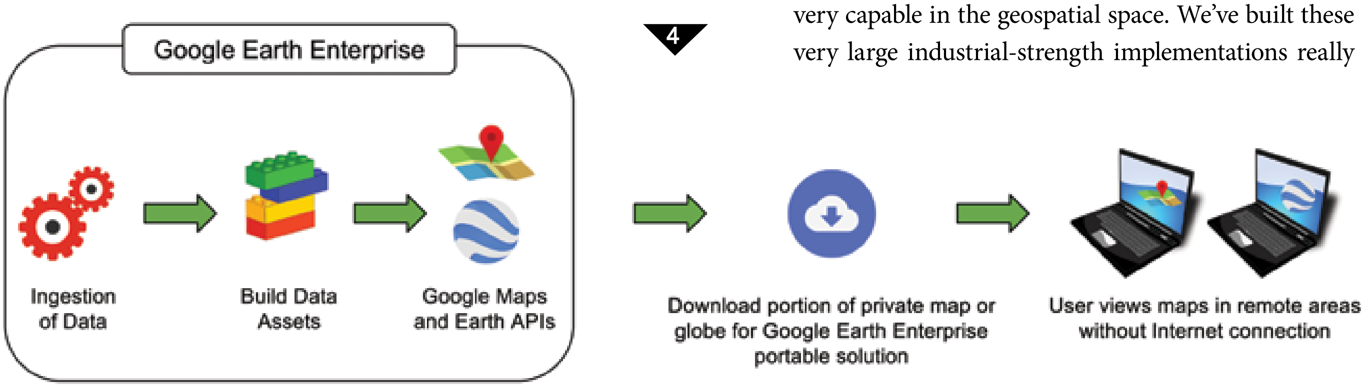
This recognition strengthened the argument to open source GEE. So, after final approval from Jen Fitzpatrick, Google's VP for Product & Engineering, the company began the open sourcing process. "We went through the code, sanitizing it, cleaning things up, repackaging, taking out any Google dependencies and things like that," Bhatnagar explains. "We looped our partners into this process and they have been instrumental in helping us clean up the code and prepare it for open source release. Meanwhile, our engineers were able to continue to focus on certain bugs that needed to be fixed first." In late March, Google released version 5.1.3 of GEE, its final version.

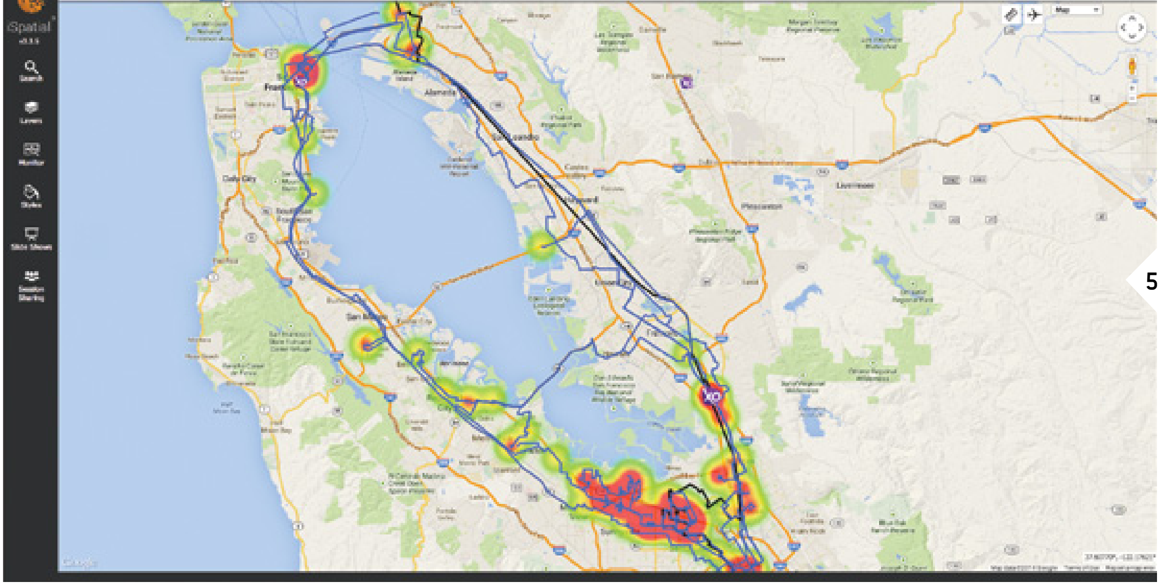
▶ FIGURE 3. Emergency response and evacuation in Washington, D.C., modeled over Google Earth in iSpatial, where zones, geofences, and routes can be merged with live incident data for staging, planning, or live operations

"There's a tremendous user community around Google Earth and GEE, and Google wanted to make sure that those users had the opportunity to continue using the capabilities with which they were familiar and that they really liked to use," says Clark. "Google also saw an opportunity to put its investment in cloud offerings to good use and open up the door for some of its imagery."

"I think it's an interesting move," says Batty. "There is a strong trend towards open source software being very capable in the geospatial space. We've built these very large industrial-strength implementations really

▼ FIGURE 4. TST's graphic showing how GEE is portable, and available offline





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▶ FIGURE 5. TST's iSpatial showing a heat map of customer density in the San Francisco Bay area, where data can be toggled from points to heat map to clusters at the click of a button

using all open source software as a base, so I think this is another interesting example of a tool in the open source space that people can use." He also thinks that GEE has some competition, as we have been sharing in the series in this publication for the past two years. He cites Cesium as an example of a product with a lot of comparable functionality, such as the fact that it can run in a browser and is very customizable. "I've seen people doing some quite interesting things with that. So I think it will be interesting to see how much traction it gets. We definitely have a trend toward a wide range of capabilities available in the open source arena."

THE PARTNERS BECOME CUSTODIANS

NT Concepts was Google's first partner focusing on geospatial solutions, starting in 2006, says Powell. "We have a long history of helping Google install and set up GEE in more than 100 customer locations around the world."

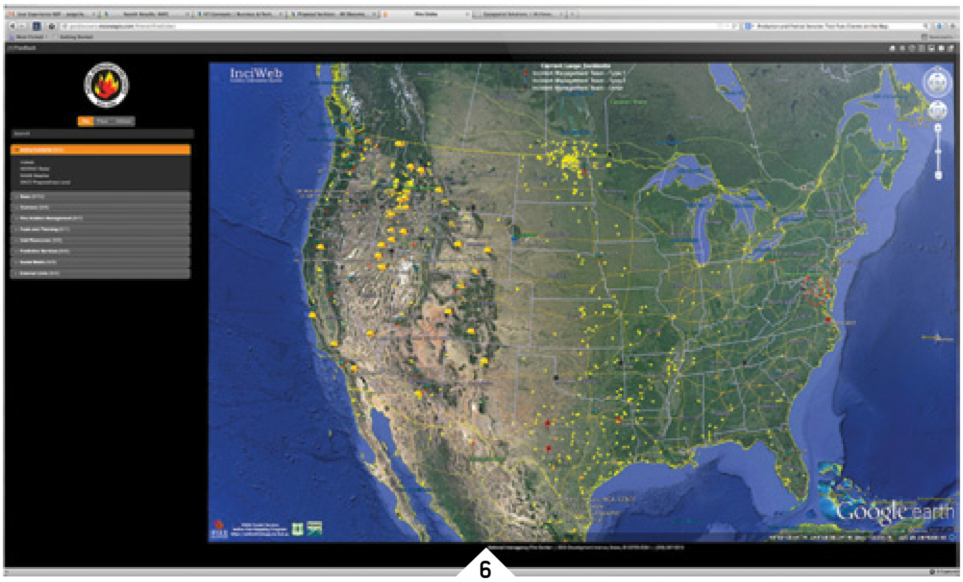
NT Concepts will be one of GEE's custodians, Powell explains, helping to manage the GitHub repository. "We'll be responsible for helping to contribute updates as people provide them to the GitHub repository and make open source improvements along with the work that we're doing. We'll be one of the groups helping to monitor that and then promote those new capabilities into the software baseline."

Google will probably stay peripherally involved and support some of the client end pieces, but it will not actively manage this process nor support the back-end server pieces, according to Powell. Large enterprise customers, in the public and private sectors, will be able to adopt the open source baseline. To make any enhancements to the GEE baseline, these users will have to download the software code and work either internally or through a firm like NT Concepts, Powell explains. "We have engineers that Google trained over the last month on the software baseline, so we have a very good understanding of what the software does. But they will have to compile that against whatever operating system that is supported in their organization—such as Ubuntu or Red Hat Enterprise Linux—that would also be compliant with the Google Earth products."

The GitHub repository, he points out, will not have an installable version of the software available for download. It will, however, contain the source code that would allow users to download it, compile it against their operating system, and then create an executable version of the software that they could then install.

TST initially reached out to Google shortly after it started, in 2007, recalls Clark. "We were trying to bring in more capability for U.S. embassies. Our organization had a lot of spatial engineers and other software developers, so, over time, we were able to extend on top of the GEE capability with a few products. We were also able to start providing some engineering input to Google teams as they looked to evolve GEE. Eventually, it just became a very close relationship. When GEE was set for deprecation, we decided to continue to support customers that had it." TST invested in keeping an engineering team dedicated to Google's mapping products and began to do a lot of work around the Maps API for its private sector customers.

Because GEE has been in deprecation for two years, Clark points out, it requires a lot of feature enhancements, maintenance, bug fixes, and security updates. "We want to ensure that the open source community knows that there's an entire product team on our end that's going to be handling support for a lot of day-to-day kind of things," he says. "Once this gets out



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▲ **FIGURE 6.** InciWeb showing fire instances in the U.S., uses GEE to deliver scalable, on-demand solutions leveraging cloud-based infrastructures, mobile support, and offline/air gapped mapping for a complete operational picture. Courtesy of NT Concepts.

there, there's going to be a lot of participation from the open source community, but I think it's going to take some time and some commitment to fully get them engaged."

"I have been involved with GEE since the beginning," says Moore. "I used to work for the U.S. Army Corps of Engineers and that is how I initially got involved. We ended up purchasing one of the largest instances of GEE. We had more than 900TB of imagery, serving up all of the Army. After that, I started Navagis with the sole purpose of supporting and helping out with GEE. Google contacted us, as well as NT Concepts and Thermopylae, to help with the open sourcing process. We were able to place one of our staff full-time at Google to help with it, doing some of the programming and cleaning up the code and other things like that."

"We have a lot of GEE expertise," Moore adds, "from over the last ten years. We hope to give that to the community, continue building, continue the momentum of GEE, and help modernize it to GIS standards, so that it can continue to be relevant. We are working hand-in-hand with NT Concepts and Thermopylae so that, once it is out there, hopefully it will be used and continue to be useful." The greatest challenge in open sourcing GEE was making sure that nothing proprietary was left in the code, he added.

THE FUTURE OF GEE, ACCORDING TO GOOGLE

Going forward, Google will have "very little" relationship with GEE, says Bhatnagar. "Part of the understanding for this open sourcing was that we really want the partners and the community as a whole to take the reins on this effort," he says. "Our engineers may continue to review code changes and merges and that kind of thing, more as a side project, but Google is definitely not committing any resources to maintaining GEE." This, he points out, is unlike other Google projects, such as TensorFlow, Android, and Chromium, which the company still very much supports and maintains.

The GEE client "will definitely remain in use for quite some time," says Bhatnagar. "From what I've heard from our users and the partners, people love the GEE client." Google's client team will continue to maintain it. "I can't say for exactly how long, but it is not going away any time soon." The GEE client, he explains, is 99 percent the same as the Google Earth Pro client. "The key difference is that when you launch the GEE client, you get a dialog box asking you for the URL of the Earth server to which you want to connect." In the future, whenever Google releases a new version of Google Earth Pro, it will also release a new version of the GEE client.

By contrast, Bhatnagar hopes that users migrate away from the Google Maps API toward

> "One of the great things... is that it can handle very large datasets, including 3D terrain and 3D globes. We want to extend that, so that we are able to handle very large 3D models as well, such as data coming from self-driving cars, UAVs, and LiDAR. We want to keep extending it so that it works on every device out there, such as mobile devices, and in the cloud."
>
> —DAVID MOORE

something like Leaflet, an open source implementation. The Maps API, he explains, will remain closed. The version bundled with GEE "is a rather crippled version of the Maps API, because it never reaches out to Google.com, so you don't get the geocoder or the street view or directions API, things that rely on Google back-end services." So, Google plans to maintain it for perhaps a year or so. "After that, either customers switch to Leaflet or, if they really want the Maps API, they can load the JavaScript libraries from Google.com, just like all the other developers do."

"One of the great things that GEE does that many other products don't do," says Moore, "is that it can handle very large datasets, including 3D datasets. It can handle 3D terrain and 3D globes. We want to extend that, so that we are able to handle, say, very large 3D models as well, such as data coming from self-driving cars, UAVs, and LiDAR. We want to keep extending it so that it works on every device out there, such as mobile devices. We also want to extend it so that it will work in the cloud."

Open sourcing, Clark says, will provide an opportunity to start bringing into GEE many new features that users have requested over the last three to five years. He thinks the product will benefit many industrial users, such as utilities. "Anybody who goes offline or needs some kind of imagery, terrain, maps, or content solution that works directly with the Google Earth client is now going to have that option. That's really big when you're talking about that client because of the billion downloads over the years. There is such a tremendous number of regular users who depend on Google Earth to do things in their day-to-day work. Ultimately, this opens up the opportunity for them to take something light and portable, add some imagery, add some terrain, and maybe weave it into their business operations."

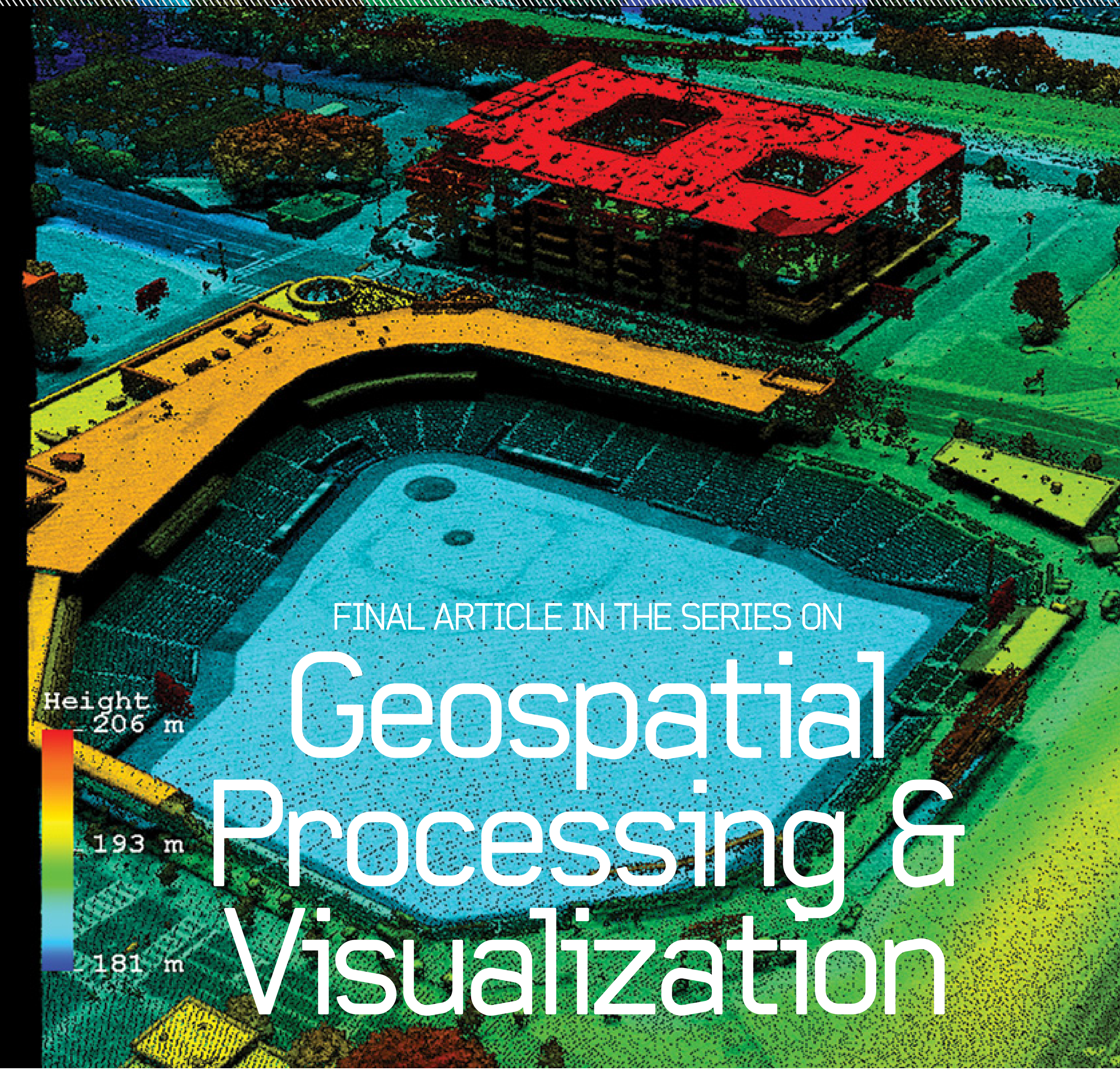
"This is something that I have been hoping would happen for a long time now and I am very happy that Google's done it," Moore adds. "GEE has been critical to the success of our company, so I am really happy that we are able to continue using it, extend it, and use it for our customers."

CONCLUSION

"We are really hoping that customers and users continue to evolve GEE in ways that we never expected," says Bhatnagar. "It was developed almost ten years ago and so much has changed since then that we love to see it going in new directions, such as being scaled to much larger grids, especially if they are in the cloud—preferably, of course, Google's cloud—to increase its processing potential. Now that it is open source, there are so many opportunities!

The open sourcing of GEE "will greatly change things," Powell predicts, "because there are many features that have been desired and requested by users over time that now organizations will be able to incorporate into their own work flows and tool sets. They'll be able to create robust portable solutions that will allow them to take data and use it on a mobile device that doesn't connect to the Internet." The decision affects many users, companies and organizations in positive ways. Users now have many choices for managing and analyzing geospatial data, including the open source version of GEE, all the products that we have profiled in the last two years in our series about the deprecation of GEE, and many more, as well.

FIGURE 7. Current and former Google staff and partners who contributed to GEE over the past decade and who helped to open-source it, at a farewell party in late March 2017. From left to right: Kevin Guerra, Asmita Wankhede, David Moore, AJ Clark, Preston McAllister, Mark Wheeler, Jordon Mears, Avnish Bhatnagar, Bret Peterson, Datta Maddikunta, Andrei Selikhanovich, and Mark Aubin.



FINAL ARTICLE IN THE SERIES ON

Geospatial Processing & Visualization

Ubisense and Harris Geospatial Solutions

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

◀ **FIGURE 1.**
The Harris Geiger-Mode LiDAR wide-area mapping system captures 3D point cloud information at densities exceeding 100 points per square meter

THE LINE BETWEEN VENDORS OF GEOSPATIAL SOFTWARE and providers of geospatial data is increasingly blurred, as more companies either provide both or partner with complementary companies. An example is a new joint offering among Harris Geospatial Solutions, DigitalGlobe, and Esri. The emphasis in the geospatial industry is increasingly on easy-to-use mobile applications that can be deployed on all major platforms, ingest external data, and run offline.

For this seventh and final installment in this series, I interviewed Peter Batty, CTO of the Geospatial Division of Ubisense, and Stuart Blundell, Director of Strategy and Business Development for Harris Geospatial Solutions, a business unit within the Harris Space and Intelligence segment of the Harris Corporation. Between them, they have more than 60 years of experience in the geospatial industry.

UBISENSE

This series has been exploring the offerings of a wide range of geospatial companies, addressing different problems in different verticals and often focused on very specific application areas and markets. This diversity shows that geospatial technology has been maturing and becoming more commoditized, says Batty. His company is working on Web and mobile solutions, mainly for utilities and communication companies, using a lot of open source software.

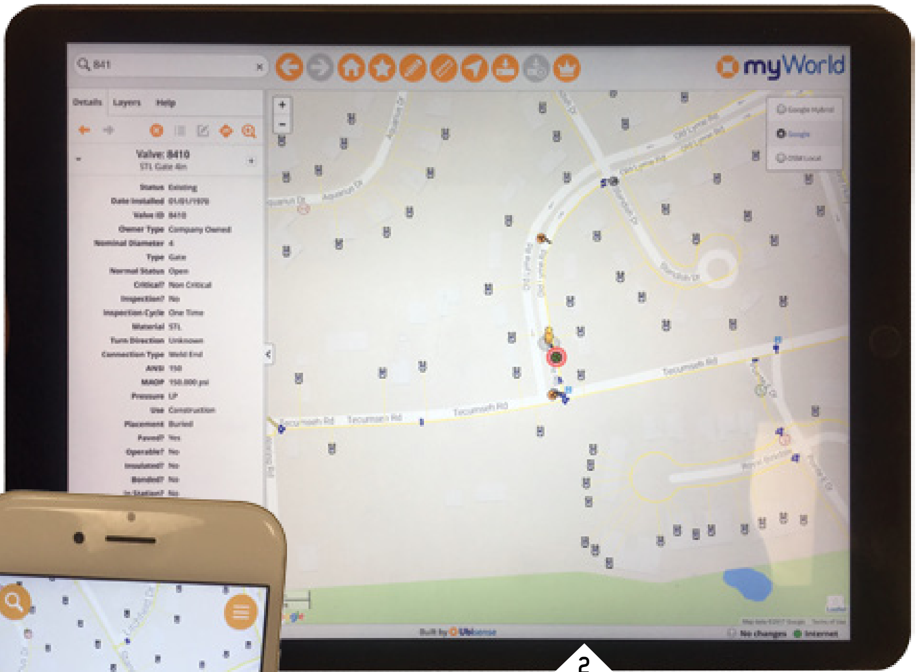
Batty, who was previously CTO at Intergraph and at GE Smallworld, has been quite involved in open source software in the past decade. He sees the possibility of Ubisense expanding in the future into new markets that share key characteristics with utilities and telecoms, such as local government or transportation, a space in which he has worked for a very long time. “We have a Web and mobile application called myWorld that addresses that market,” he says. “We really try to deliver applications that leverage geospatial data and are simple to use for the 95% of the people in an organization who don’t know how to use GIS, such as field technicians, operations people, and customer service representatives.”

The advent of Google Maps, he recalls, changed the industry, as customers began to ask him why their expensive enterprise GIS was not as fast and as simple to use as Google Maps. In response, says Batty, Ubisense delivered a product “very much in the style of Google Maps,” which it also uses as a data source. However, after starting out using the Google Maps JavaScript API, over time Ubisense transitioned to using a lot of open source code as the basis for its products, such as a Leaflet JavaScript API in the PostGIS open source database. “I’m very impressed at the capabilities of geospatial open source software these days,” says Batty. “We’ve certainly used it to build some very large and robust implementations.”

Ease of use is a key focus for Ubisense, says Batty. He thinks that it is “deceptively hard to achieve,” especially for the traditional GIS vendors, who struggle to make software for nontechnical end users. “When you’re used to having these very powerful products, it’s really quite hard to leave functionality out.” Ubisense is proud of the top score it received for usability in a user satisfaction survey that one of its customers, a very large U.S. cable company, does every time it rolls out a new IT system.

Ubisense is a Google business partner and therefore can resell Google licenses. Typically, companies use Ubisense inside their firewalls, so they have to pay for the use of Google Maps, which they can buy either through Ubisense or directly from Google. However, Batty points out, Ubisense is not exclusively tied to Google. Because its software is built on open source, its users can take advantage of similar map services from other

Editor’s Note:
Google Earth Enterprise (GEE) will become open source. This brings an end to our two-year series on options for organizations that would be looking for other solutions. The full story on Google’s decision to open source GEE, with a first-person interview with Google, appears on page 14.



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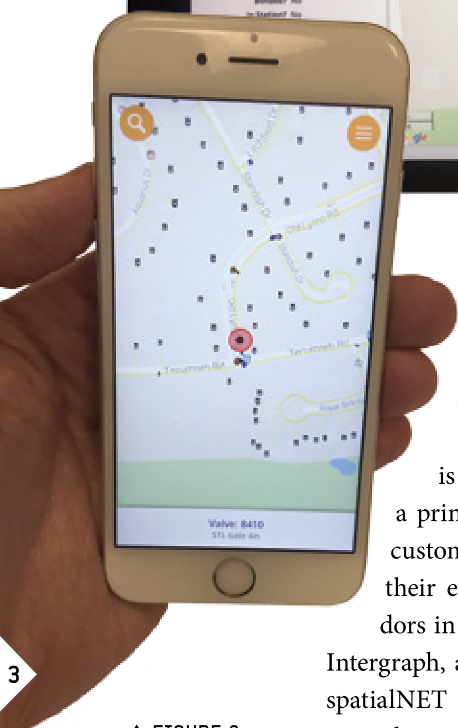

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▲ FIGURE 2. Ubisense product myWorld with gas utility data running on an iPad, with the data available online or offline

▲ FIGURE 3. myWorld showing the same gas utility data on an iPhone, with a simplified user interface suitable for the smaller mobile screen

companies, such as Bing, MapQuest, or OpenStreetMap (OSM). Ubisense also makes a lot of use of OSM data for offline applications, which Google doesn't allow with its data.

Another key focus area for Ubisense is integration. In general, Batty explains, a primary data source for his company is its customers' detailed network and asset data in their enterprise GIS. The dominant GIS vendors in the utilities market are GE Smallworld, Intergraph, and ESRI; the telecom market also uses spatialNET from Synchronoss. Ubisense has systems that integrate with all four of those platforms. Therefore, Batty says, "myWorld gives our customers a sort of near real-time view of what's happening across their enterprise."

Ubisense's biggest focus in the past couple of years has been on developing mobile applications. According to Batty, this is an area on which the major GIS vendors have not focused as much or in which they don't have a very coherent strategy. "The nature of what you can do with mobile applications has changed dramatically in recent years," he says, "in particular with the development of modern tablets and smart phones and widespread wireless networks." By contrast, large enterprises are often slow to adopt these changes; therefore, they mostly rely on mobile solutions that predate them. "They're often running on quite old Windows devices and are not designed to take advantage of wireless networks." Ubisense saw this as an opportunity.

Despite the significant growth in wireless network coverage, Ubisense's customers also need to be able to run mission-critical applications, such as repairing an electric network, offline. Therefore, Ubisense put a lot of work into building a very robust capability to synchronize geospatial data offline, says Batty. This, he explains, is a challenge that has not been widely solved and commoditized and still requires a lot of development. Building a hybrid online and offline mode while keeping the data synchronized turned out to be more complex than he had anticipated.

Another key to mobile solutions is the ability to run on all the major mobile platforms: Android, iOS, and Windows. Ubisense's large enterprise customers still have many people using Windows, for example on laptops in trucks, and they are also seeing a trend towards greater usage of Android and iOS tablets and phones. "We use a technology called Apache Cordova, also known as PhoneGap, to write applications using HTML and JavaScript. Then you can in effect compile that code to run as a local app on all of those three platforms, including any customizations that the customers or we ourselves might make," says Batty.

Ubisense provides "an application framework," Batty says, that includes a base application that can run out of the box, arranged with standard features such as one box search, Google Map-style navigation, and Street View display. However, he points out, users can configure many aspects of it, including the data layers and certain aspects of the functionality, using a configuration user interface. Ubisense also provides users with an API that they can use to develop more complex additional functionality. "In general, we work with large customers and all of them tend to have some unique requirements, so it's important to have this customization environment and also to have an approach that lets you deploy that to all of the different operating systems easily."

Ubisense also uses its platform to deliver some specific applications, such as to enable electric utilities to assess damage after a storm and to help gas, electric, and communications companies to conduct inspections and surveys.

Batty agrees that the line between software vendors and data providers is blurring. While Ubisense mostly deals with data coming from its customers' internal enterprise systems, it also makes it easy for them to integrate other data sources. "We support the Esri REST API and OGC Web services, including WMS and WFS," he says. Even large enterprises that historically have been mostly focused on internal data now increasingly have access to external data, he points out. "We make it very easy to integrate that in."

There are some parallels and some differences between Ubisense and Google Earth Enterprise (GEE). At least a couple of utilities, Batty says, have built solutions to allow them to visualize data from myWorld using Google Earth. However, he points out, the 3D aspect of it was peripheral. Ubisense provides a more Google Maps-style flat interface and does not support a spherical Earth visualization. "3D isn't really needed for the great bulk of our applications," Batty says. "In general, for us it's useful to be able to run the app in a Web browser, because we deploy to very large numbers of users in an enterprise as opposed to having to install a client application." For organizations that have been using GEE without fully leveraging its 3D capabilities and the sphere capabilities, "we provide something that is comparable and more customizable and that lets you take data offline more easily."

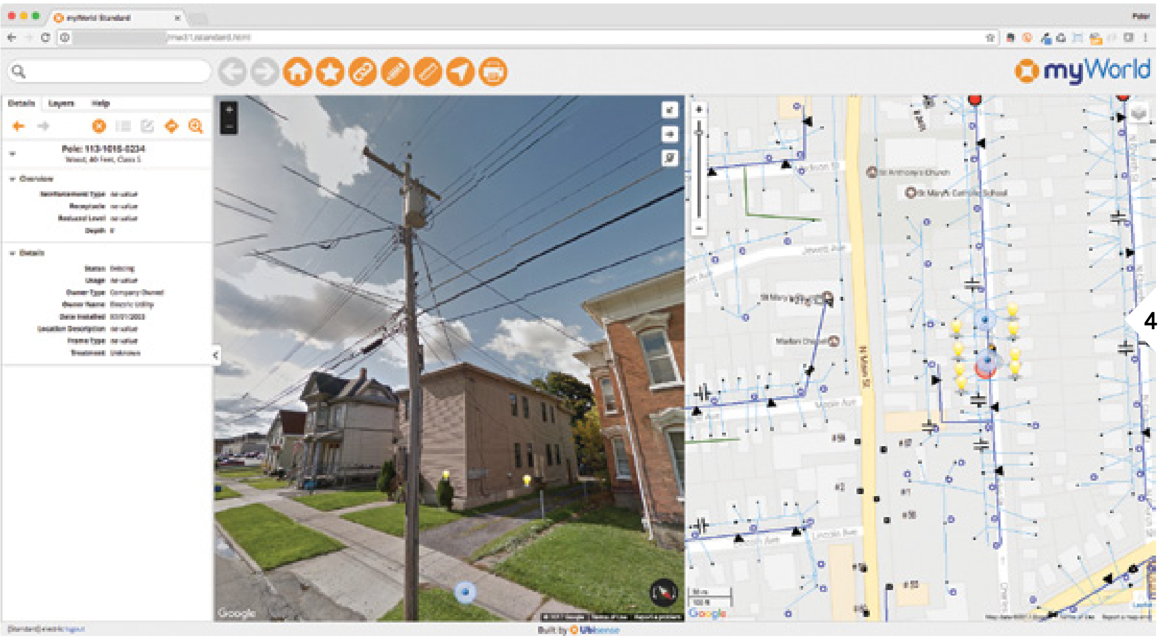
HARRIS GEOSPATIAL SOLUTIONS

Harris Geospatial Solutions focuses on the use of geospatial technologies—including data, content management, exploitation services, and software tools—in both the private sector and the U.S. government. On the private sector side, Harris is investing in analyzing data from satellite imagery, mapping in 3D using airborne Geiger-mode LiDAR, and developing solutions for such markets as precision agriculture, utilities, and critical infrastructure.

To capitalize on the growth in demand for Earth observation (EO) data, Harris has partnered with DigitalGlobe and Esri to offer a subscription service they call AllAccess+Analytics. The service gives customers access to the entire DigitalGlobe archive, via DigitalGlobe's Geospatial Big Data Platform (GBDX), and allows them to analyze the imagery using Harris' ENVI analytics tool and Esri's analytical tools. "We see the trend of delivering information as being really important towards achieving growth and profitability in the geospatial analytics market," says Blundell.

In 2015 Harris put on the market a wide-area LiDAR mapping technique called Geiger-mode LiDAR, previously reserved for military applications, which collects data with spatial resolutions on the order of 20-40 points per square meter. It can be used to collect high-resolution 3D imagery in both urban and natural environments, enabling users to visualize fine details and collect the attributes of features.

In February 2015, the company bought Exelis,



◀ FIGURE 4. myWorld with electric utility data, integrated with Google Street View, enabling the user to see details of equipment on the pole, courtesy of Ubisense a smaller rival that had been spun off from the ITT Corporation in 2011, and that developed the ENVI suite of remote sensing processing tools. According to Blundell, this put Harris "at the top of the remote sensing technology pyramid in terms of both engineering and manufacturing expertise."

Harris also focuses on critical infrastructure, including utilities, transportation networks, ports, and harbors. The company is working with Canadian company exactEarth to support worldwide maritime ship tracking in near real-time, says Blundell. Harris supports its utilities customers with LiDAR mapping of both the transmission and the distribution portions of their networks, for asset management and disaster response. "We see the concept of persistence in remote sensing as adding value to a variety of vertical markets," Blundell says. "Harris works with a variety of remote sensing platforms, including UAS, airborne, and satellites to provide full-spectrum remote sensing solutions."

Blundell, too, agrees that in the geospatial market the distinction between software vendors and data providers is blurring. He sees this as a reflection of what is happening in all markets, namely that content is increasingly critical to attracting and retaining customers. He contends that his company's online marketplace will become "the premier provider of geospatial content" for several reasons, including because it provides "a unique geospatial data broker service with content from more than 40 different geospatial companies," including Airbus, DigitalGlobe, OpenStreetMaps, and smaller companies that provide vector data layers.

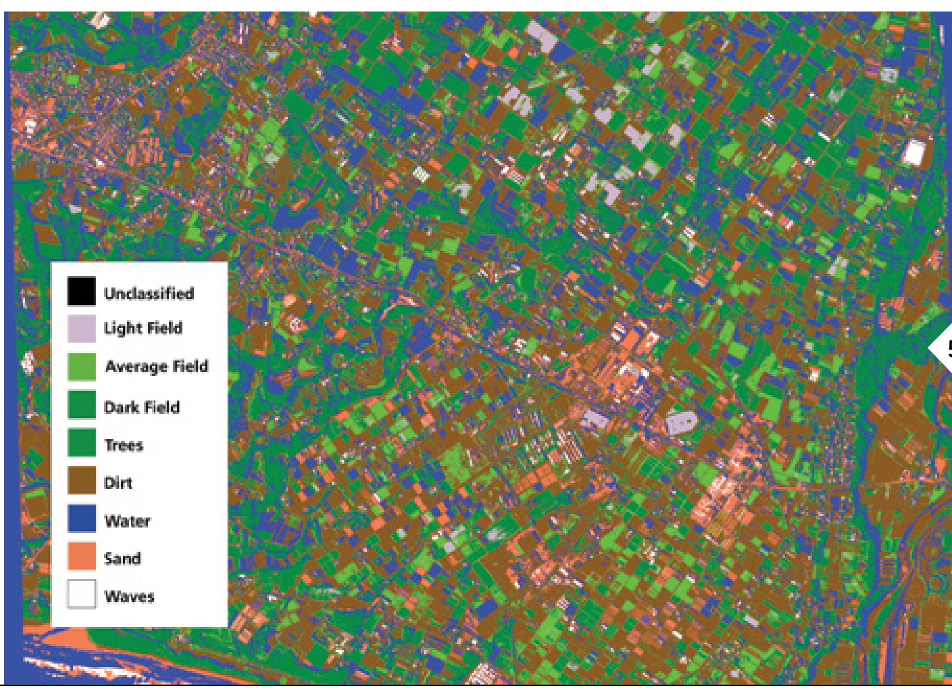
The second reason, Blundell says, is that it provides "data curation and custom product generation services" by integrating several data sources to meet each customer's unique needs. To illustrate the importance of this, he points to questions about the quality of sensors when dealing with data from large constellations of small satellites. "What is the core imaging quality of some of these sensors? How do you reconcile quality metrics when you're getting a stack of data from 15 different collections over an area of interest? How do you bring that data together into a cohesive, mosaicked image dataset?" He argues that Harris' experience makes it especially qualified to address those issues and ensure quality. Additionally, he argues, Harris is particularly skilled at understanding how to extract information from space-based sensors due to its long experience with radar data and various kinds of sensors.

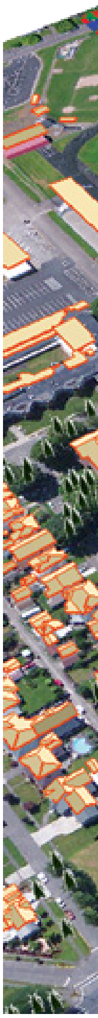
In the future, Blundell says, Harris may partner with large organizations, such as IBM, and smaller companies that can extract geolocation data from text and other social media feeds. "We see that as being an important part of the location-based information mix going forward." The NGA and other U.S. government agencies are increasingly using open and commercial data sources and Harris, he argues, has a role in helping the U.S. government and its private sector customers find the right data to meet their mission requirements.

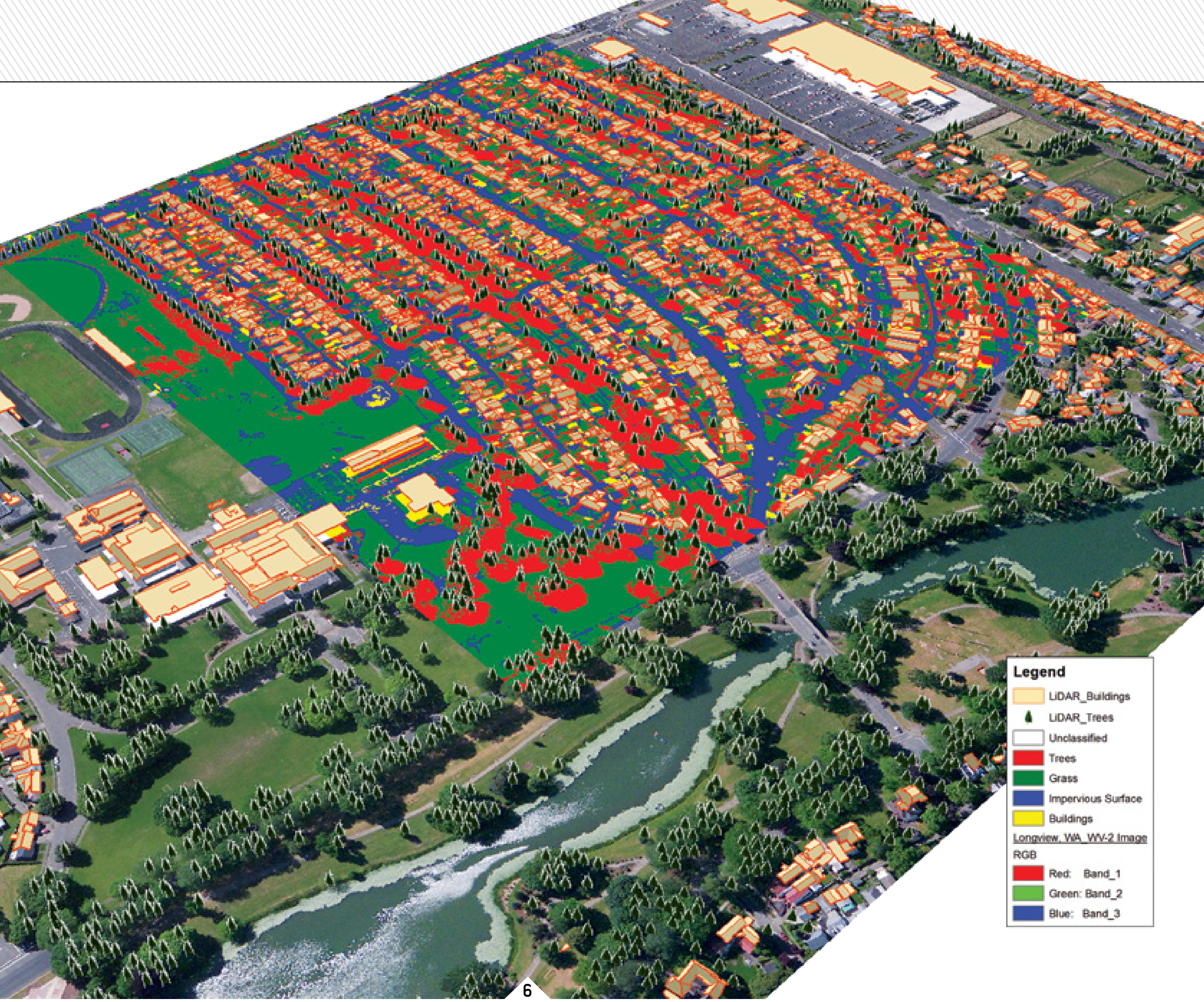
Harris does not provide a Google Earth-type enterprise software platform. However, to provide that capability to its customers, says Blundell, the company has always worked with such partners as Esri, with which it recently signed a new partnership agreement. He also cites a partnership with SARscape, a small company that builds commercial radar processing capabilities, which Harris integrates with its ENVI image processing software.

Harris, Blundell says, contributes to platforms like Google

▼ FIGURE 5. An example of land-cover classification services with ENVI Analytics from the Harris Geospatial Marketplace







Earth and ArcGIS its expertise and reputation in the collection and processing of geospatial data, such as those from hyperspectral or radar imaging. Citing a comment that Lawrie Jordan made years ago when he was the president of ERDAS, to the effect that the map of the future is an intelligent image, Blundell foresees "an intelligent image where the information is fused into the scene." Background search capabilities and machine learning, he argues, will automatically make available a variety of statistical information. "Increasingly, I see embedded intelligence within imagery as being the key towards getting revenue growth from the larger consumer market."

CONCLUSIONS

This series of articles has offered a panorama of geospatial offerings from 18 companies: Esri, VRICON, Google, Galdos Systems Inc., Skyline Software Systems, Onix Networking Corp., CartoDB, DigitalGlobe, Analytical Graphics, Inc., Mapbox, PIXIA, Luciad, BAE Systems, Earthvisionz, Hexagon Geospatial, PYXIS, Ubisense, and Harris Geospatial Solutions. While they each provide a unique set of products and services, these companies compete, partner, and overlap in that ever-changing kaleidoscope image that is the geospatial industry, displaying patterns soon to be replaced as technology and user expectations advance.

▲ **FIGURE 6.**
An example of Harris Geospatial Earth observation imagery with integrated 3D LiDAR data and image processing services

Global Ocea

New Tools for Storm and Sea-Level Modeling, Coastal Planning, Hazard Mitigation

KRISTINA BAUM / WORLDDEM MARKETING AND PRODUCT MANAGER &
JOHN COLLINS / RADAR PRODUCTS TECHNICAL SALES MANAGER / AIRBUS DEFENCE AND SPACE
DR. HANS C. GRABER / EXECUTIVE DIRECTOR / CSTARS

Cartography of the world's ocean shorelines goes back to the voyages of the first great explorers, when mapping was done by sight. Cartographers created maps based on what could be seen by boat and from the coast itself. The detail and accuracy of these maps were completely dependent upon the physical and intellectual capabilities of the cartographer. Over time, improved surveying techniques led to the generation of more detailed, precise maps, and with the arrival of aviation, cartography moved its observation post and took on new heights.

Thanks to aerial photography from planes, airships and balloons, it became possible to access views of wider areas more rapidly. A new era of mapping had begun. A further giant step was achieved when the first Earth observation satellite, Landsat, was launched in 1972. Images acquired by Earth observation satellites enabled cartographers to reach new horizons with the ability to view hundreds of kilometers of shoreline in a single picture taken from space.

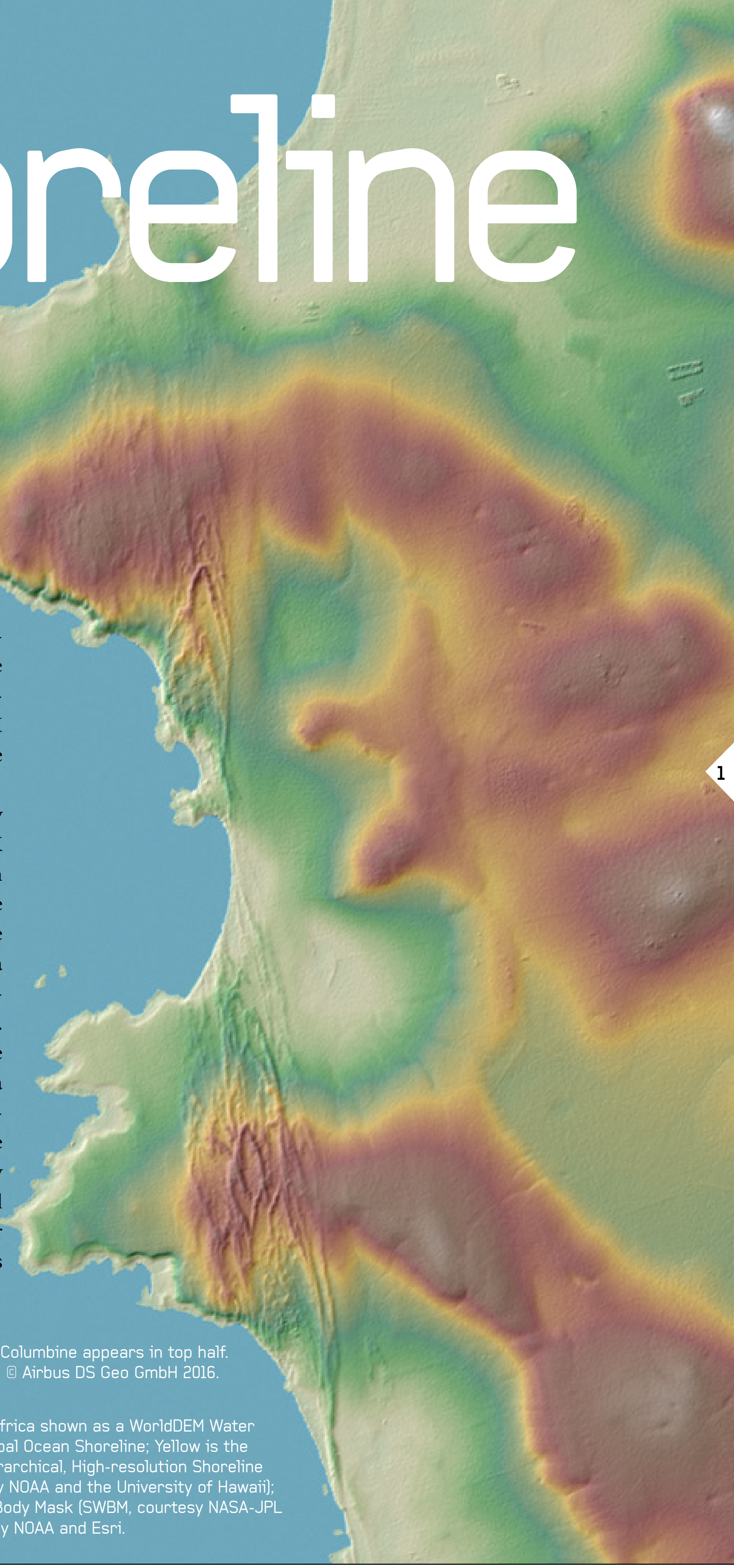
Shorelines are influenced by the geology and topography of the surrounding landscape as well as water-induced erosion caused by waves, currents and tides. Therefore, in addition to a full view of the area, an up-to-date and detailed Digital Elevation Model (DEM) is required to precisely map them. For nearly 40 years, Earth observation satellites have played an important role in developing a synoptic understanding of surface conditions, including the geology, terrain and surrounding environment. Among the extensive global DEMs derived from Earth observation satellites currently available, Airbus Defence and Space's WorldDEM provides highly detailed shoreline mapping with a unique and homogeneous information source.

One of the offshoots of producing the WorldDEM is the delineation of the extents of water bodies (including oceans) at a consistent scale, worldwide. Airbus Defence and Space is harnessing this information to produce the Global Ocean Shoreline product, which brings a new dimension of accuracy and currency to the marketplace. Global Ocean Shoreline is intended to replace existing global or sub-global shoreline datasets, such as the Global Self-consistent Hierarchical, High-resolution Shoreline database (GSHHS) and the SRTM Water Body Mask (SWBM). Both vector datasets are at a lower resolution, and not as up-to-date as Global Ocean Shoreline. GSHHS was derived from several sources, over different time periods, leading, in many places, to an inaccuracy of several hundred meters, whereas SRTM data is now over 16 years old and does not extend North or South of 60° latitude.

WORLDDEM: HIGH RESOLUTION ELEVATION INFORMATION

WorldDEM is the first elevation model to provide truly pole-to-pole coverage, and it offers unique accuracy and quality, surpassing that of any global

n Shoreline

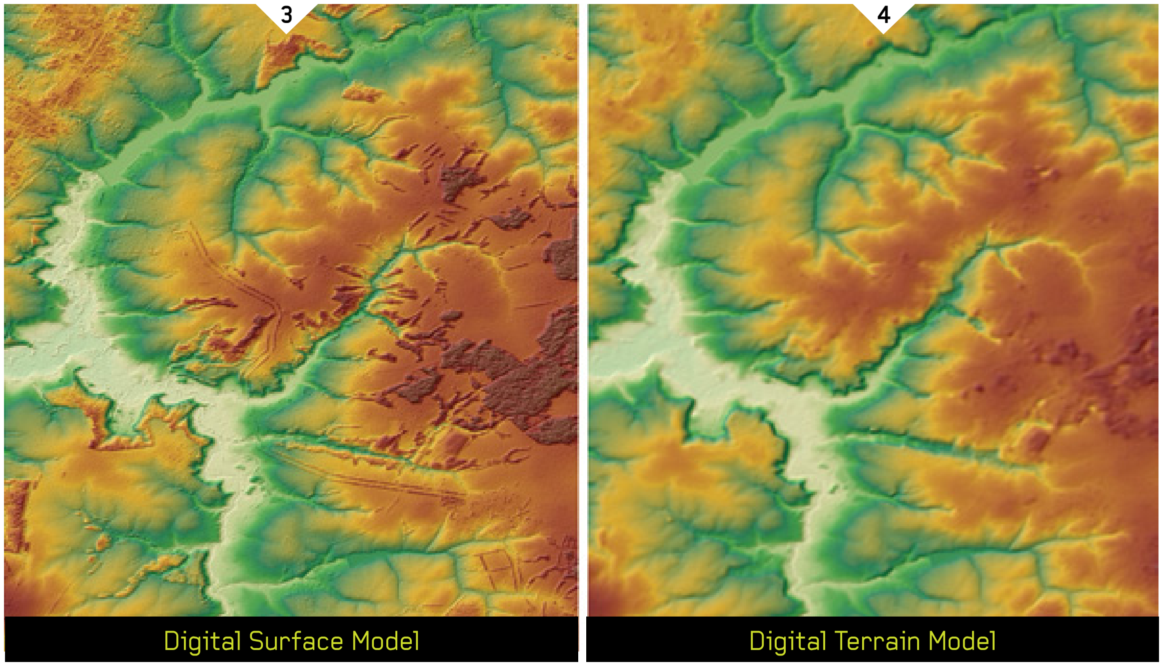


satellite-based elevation model available today. Its relative vertical accuracy of 2m and better than 4m absolute accuracy (in a 12m x 12m raster) defines a new standard in global elevation modeling, making WorldDEM a reliable and precise reference layer to enhance a wide range of applications.

The input data for the WorldDEM was acquired by the German radar satellites TerraSAR-X and TanDEM-X during the TanDEM-X DEM mission, implemented in the frame of a Public-Private Partnership between the German Aerospace Center (DLR) and Airbus Defence and Space. Both satellites started the synchronous data acquisition in 2011 by forming the world's first free-flying, high-precision radar interferometer in space. They completed two coverages of the Earth's entire landmass, and covered more complex areas with a third and fourth acquisition campaign to ensure consistent high quality and accuracy of the final product, in less than four years. The two satellites

▲ **FIGURE 1.**
DEM of South Africa. Cape Columbine appears in top half. Courtesy DLR e.V. 2016 and © Airbus DS Geo GmbH 2016.

◀ **FIGURE 2.**
Cape Columbine in South Africa shown as a WorldDEM Water Body Mask. Blue is the Global Ocean Shoreline; Yellow is the Global Self-consistent, Hierarchical, High-resolution Shoreline Database (GSHHS, courtesy NOAA and the University of Hawaii); Pink is the Shuttle Water Body Mask (SWBM, courtesy NASA-JPL and NGA). Imagery courtesy NOAA and Esri.



▶ FIGURE 3-4. Vladimir, Russia, shown both as a WorldDEM Digital Surface Model (left) and Digital Terrain Model (right). Courtesy DLR e.V. 2016 and © Airbus DS Geo GmbH 2016.

flew in a very close formation with distances of as little as 150m between them, a technical feat that had never been tried before and worked with perfect reliability for more than three years.

Airbus Defence and Space is responsible for the adaptation of the elevation model to the needs of commercial users worldwide and refines the DEM according to customer requirements, e.g. editing of water surfaces or processing to a Digital Terrain Model (representing the bare Earth's terrain). Three main WorldDEM products are available: an unedited Digital Surface Model (DSM), an edited DSM, and a Digital Terrain Model (DTM). The edited Digital Surface Model consists of a hydro-enforced DSM with water body features derived from radar imagery. It serves as the basis to produce the Global Ocean Shoreline.

THE INCEPTION OF GLOBAL OCEAN SHORELINE

Since the geographically-limited SRTM Water Body Mask was developed over 16 years ago, there has been no new commercially available shoreline product that covers the Earth from pole-to-pole and 360° degrees around. To fill this gap and generate a new global vector product accurately delineating the world's ocean shorelines, Airbus Defence and Space has entered into a cooperation agreement with the Center for Southeastern Tropical Advanced Remote Sensing (CSTARS) at the University of Miami in the U.S., to create the Global Ocean Shoreline product.

CSTARS has a long history of combining excellence in oceanography and the latest in remote sensing technologies. One of the major goals of CSTARS is the monitoring of the oceans and changing ocean shorelines worldwide, be they natural or manmade. The ability to monitor these changes on a global scale requires CSTARS to have access to the most up-to-date geo-information from multiple optical and radar sensors. Through its network of satellite ground stations, CSTARS is able to access accurate and timely satellite imagery as needed, to service a variety of research and practical uses.

The production of the edited WorldDEM consists of flattening the water surfaces of lakes and reservoirs to a single elevation, setting rivers and canals to a monotonic flow, and setting oceans to zero meters. The shorelines of all water bodies are detected using the radar (amplitude) images of the WorldDEM product. Because radar waves are reflected away from the radar sensor by smooth and flat surfaces such as water, water has a consistently black appearance in these images. This allows for the semi-automatic detection of shorelines during the WorldDEM water editing process. Once waterbodies are detected, they are further classified into lakes, rivers and oceans. This classification and the extent of the water bodies are combined to create the WorldDEM Water Body Mask.

The WorldDEM WBM is a raster file with the three types of water bodies identified, in addition to land (or not water) making it a valuable record of the extent of lake, river and ocean shorelines on a global scale. However, it is understood that many users of geodata would find it more convenient to have a simple vector

file of ocean shorelines, rather than a large series of raster files; hence the Global Ocean Shoreline was born.

The Global Ocean Shoreline is derived from the WorldDEM following several intermediate steps. First, all water surfaces are delineated to generate a Water Body Mask which is used to detect the ocean shorelines. The WBM is a raster file that needs to be objectively converted into a consistent vector, free from gaps and crossing segments suitable for coastal applications. CSTARS' expertise in ocean shoreline environments is used for additional vector correction to account for any recent temporal changes (new ports, marinas, jetties, breakwaters, beach erosion or accretion, etc.) by comparing the shoreline to the latest available satellite imagery. The resulting Global Ocean Shoreline is a homogeneous, gap-free and up-to-date database.

Airbus Defence and Space's Global Ocean Shoreline offers a consistent and uniform horizontal resolution of 12m, using vectors without any typological errors, gaps or kinks. The standard Global Ocean Shoreline delivery is in Esri shape file format, while other vectors formats are possible, on demand.

OPENING A NEW RANGE OF APPLICATIONS

Global Ocean Shoreline, thanks to its high-resolution at a global scale, can support a wide range of applications. It offers the accuracy required for tsunami or hurricane storm surge inundation modeling, and sea-level rise studies as well as coastal and littoral spatial planning, hazard mitigation and community preparedness. Indeed, anyone who uses GIS applications will welcome a more accurate land/ocean boundary for clipping datasets to the ocean's edge.

The Global Ocean Shoreline will be globally available at the end of 2017, with progressive availability of full continents throughout 2017. While the focus of this particular new WorldDEM product is ocean shorelines, the production process is equally adaptable to lakes and rivers worldwide, as these can be produced in vector format, on request.

▲ FIGURE 5. Turuépano National Park in Venezuela, via radar satellite TerraSAR-X. Courtesy DLR e.V. 2011 and © Airbus DS Geo GmbH 2011.

An Economy for HUMANITY

Transitioning to an Economy for a Thriving Humanity and Planetary Future

BY HANS-PETER PLAG AND SHELLEY-ANN JULES-PLAG
WWW.ECONOMY4HUMANITY.ORG

HUMANITY AND THE EARTH'S LIFE-SUPPORT SYSTEM

The notion of our planet being a life-support system for all life plays a central role in understanding humanity's relationship to the planet. Humanity is embedded in, and dependent on, the "Earth's Life-Support System" (ELSS). Communities of human and animals interact with the ELSS through flows of energy and matter (***Figure 1***); they take from the ELSS what they need to sustain the population, and they give back to the ELSS what remains after they have processed matter and changed the state of energy. All communities impact the ELSS in a complex way, and their interactions can improve or degrade the state of the ELSS with consequences for all other communities depending on the ELSS.

Humanity has achieved a unique position in the ELSS and has the means to significantly change the state of the ELSS. Propelled by access to seemingly unlimited energy and technological progress, human population growth, with associated resource consumption, habitat transformation and fragmentation, and climate change, have degraded the ELSS. This degradation has pushed the system out of an exceptionally stable state that has provided a "Safe Operating Space for Humanity" (SOSH) during the Holocene (Rockström et al., 2009) into a rapid transition to a new but yet unknown state. Humanity is "reengineering" the ELSS at global scale and changing its physiology

Editor's Note:
The current political situation in the U.S. with Donald Trump as President and using his position to personally increase his wealth demonstrates that the value of money over anything else is at an all-time high. It also shows the dire need for changes like those suggested in creating an economy for humanity.

fundamentally (including but not limited to the energy, water, Carbon, Nitrogen, and Phosphorous cycles), is mobilizing and adding new constituents into these cycles, and is rapidly reducing the number and diversity of non-human animals.

A large fraction of the Earth surface has been changed to meet our needs, and as a result, the extinction rate is accelerating and is now at an unsustainably high rate (Barnosky et al., 2012). In an analogy to medicine, humanity has developed into the "anthropogenic cataclysmic virus" (ACV) in the ELSS (Plag, 2015). To reach sustainability, this virus is challenged with a transition into the healer. This transition requires overcoming the current inconsistency between normative ethics and the prevailing economic, social and governance practices.

For a species as powerful and impactful as humans have become, safeguarding the ELSS has to be a core concern if survival of our species matters. Since Adam Smith 240 years ago laid out the basis for economies as we know them, almost all interactions of humanity with the ELSS are governed by economic rules. Consequently, the extent to which communities safeguard the ELSS depends crucially on the economic model. Safeguarding the ELSS has to be inherent in the economic rules. Safeguarding the ELSS requires an economy that understands the ELSS and aims at a healthy ELSS in the same way health sciences and practitioners understand human health and aim at safeguarding our individual life-support systems.

Although the vast majority of normative ethical accounts demand that the human population transition to a fair, sustainable lifestyle, the economic rules that require perpetual growth are in tension with this moral requirement. In fact, the current rules are sustaining growth by accelerating the main mass and energy cycles in the ELSS. However, being successful for some time does not equate to being sustainable. The acceleration of the flows is leading to a cataclysmic degradation. Making progress towards an economy that satisfies our needs while safeguarding the ELSS requires a fundamental transformation of the paradigms upon which our economies are based. In an "Economy for Humanity" (E4H), the overarching goal is to ensure thriving communities by satisfying the needs of the present while safeguarding the future.

"Somehow, we have come to think the whole purpose of the economy is to grow, yet growth is not a goal or purpose. The pursuit of endless growth is suicidal."
—David Suzuki

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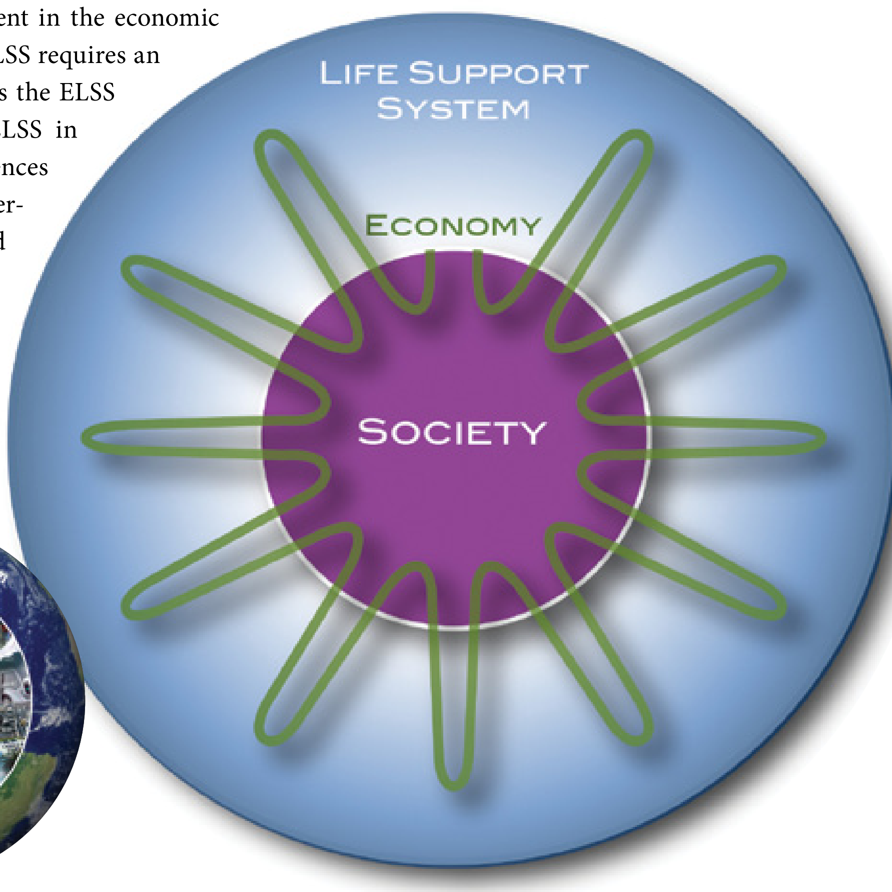

FIGURE 1. Humanity and the Earth's Life-Support System (ELSS): Most interactions between human communities and the ELSS are economic (left). Human communities interact with the ELSS through flows of energy and matter (right), and these flows are under the influence of economic rules, which in turn are impacted by social and ethical norms.

A GROWTH-ADDICTED ECONOMY AND UNSUSTAINABILITY: THE STATUS QUO

"Global sustainability is an emerging system property of the Earth's Life-Support System (ELSS), which can only be obtained if economy has the dual purpose of safeguarding the health of the ELSS while ensuring the well-being of human communities."

For more than 200 years, almost all interactions of humans with the ELSS have been controlled by economic models that disregard the wealth of the non-human environment. Adam Smith (1776) defined the purpose of economy to be the creation of human wealth, with no regard for the impact this creation of wealth might have on the ELSS. As John M. Greer (2011) states, "it would be by no means inappropriate to define all of modern economic thoughts as footnotes to Smith." One of those footnotes is the work of Milton Friedman, who redefined in 1970 the purpose of business as maximizing profit for the shareholders. Focusing totally on making money, and forgetting about any concerns for employees, customers, society or the ELSS, amplified the impact of Adam Smith's original idea. In connection with the easy access to energy and new technologies, it accelerates the degradation of the ELSS.

Only recently have we started to realize that the disregard of non-human wealth actually not only threatens our survival as a species but also endangers our economies (Heal, 2017; Korten, 2015). As summarized by Costanza et al. (2013), "the current mainstream model of the global economy is based on a number of assumptions about the way the world works, what the economy is, and what the economy is for." These assumptions originate in an earlier period, when human wealth and capital were very limited, extreme poverty was a widespread problem, and human impacts on the planetary system were minor and at local scales. Planetary non-human capital was abundant, and there was little reason for Adam Smith and others to consider any limitations of the non-human capital in developing the economic model that became the origin of today's global economy and society.

With less than a billion people on the planet, with limited access to energy and means to change the environment, with most people in extreme poverty, often exposed to famine, epidemics, and wars, it made sense to see the sole purpose of economy in as increasing human wealth and to focus on the growth of the market economy. By thinking of the economy as only marketed goods and services, the means for growing the market became increasing the amount of the products and services that were produced and consumed. Thus, increasing the flows in the ELSS became synonymous to increasing the growth of human wealth.

The current mainstream economic system leads to basically unconstrained use of natural resources and their depletion. Long-term impacts and the resulting unsustainability are largely ignored and the hope is that lost ELSS functions can be replaced by technology, generating the requirement for continuous innovation. "More is always better." Degradation of non-human capital and the loss of

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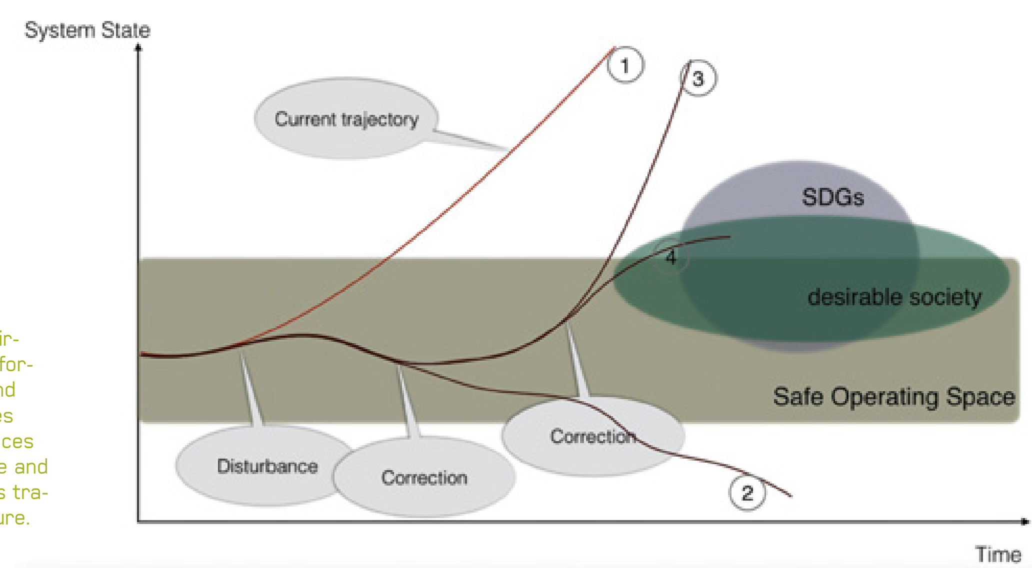


▶ FIGURE 2.
The iterative nature of bending system trajectories towards desirable futures: Achieving the transformation from the current state and trend to a desired future requires an iterative process of disturbances exceeding the system's resilience and corrections to bring the system's trajectory closer to the desired future.

functional value of the ELSS are not considered in the measure of growth being the Gross Domestic Product (GDP, Costanza et al., 2014).

The current trajectory of the ELSS points to major shifts in the system-state with unknown and uncontrollable outcomes for humanity, and to existential threats for our global civilization. The ACV is causing massive degradations of the ELSS. Changing the trajectory of the ELSS to more desirable and less threatening futures requires disturbances that exceed the resilience of our society and challenge our basic paradigms (***Figure 2***).

Only a transition to a fundamentally new economic practice, an E4H that inherently safeguards the ELSS, can divert the system trajectory towards more desirable futures. To guide our communities and economies towards this transition, it is essential to:

- provide information on the ELSS and its core functions, processes and vulnerabilities and how it connects to human livelihood;
- develop economic practices that consider safeguarding the ELSS as a natural part of economy;
- develop criteria and systems that measure the degree to which we adopt these practices.

The impacts of ethical, social, and economic rules on the ELSS physiology result from governance decisions. Although normative ethics demand otherwise, the current descriptive ethics are focused on growths of human wealth measured by inappropriate metrics favoring the acceleration of all flows between human and non-human components. Rieder (2016) identifies three normative ethical principles that are relevant to sustainability:

- Duty not to contribute to massive, systemic harms;
- Duty not to act unjustly;
- Duty not to have children who would have bad lives.

Based on the notion that the "climate change crisis" is actually a "population crisis," the author uses these principles to conclude that in the current situation of a rapidly growing population having a severe degrading impact on the sustainability of the global society, the number of children a family can reasonably have is limited to zero or one, and any larger number would need thorough justification. Applying the same ethical principles to the current economic practices shows that there is what could be termed a "production crisis," in which much of the current economy violates at least the first and second principle by causing massive harms and severe injustice due to the degrading ELSS, climate change, and the distribution of wealth.

A number of alternative economies have been proposed. For example, Jackson (2009) discusses ways to prosperity without growth. Utting (2016) argues that for the implementation of the U.N. Sustainable Development Goals (SDGs) a "Social and Solidarity Economy" (SSE) has a potentially important role to play and can lead to a reorientation of economies and societies toward greater social and ecological sustainability. The principles and practices of SSE aim to reintroduce justice and to humanize economy with innovations grounded in people's agency. The transformative potential of SSE is considered crucial for achieving the SDGs. The current mainstream economy and its wealth creation seem no longer to serve humanity (Ruggie, 2003).

Those benefitting from the discounting of natural capital in the current economic model, which allows individuals and companies to gather seemingly unlimited human wealth in money, are likely to resist any transition to a novel economy consistent with the ethical principles. Any transition from the current infinite-growth economy to one that safeguards the ELSS will be resisted by many individuals, companies, and to some extent governments. However, increasingly people across the planet understand that the current development is unsustainable and threatens the well-being of current and future generations. Many of those who realize that we are taking away the future of our children are engaging in the global unrest. Engaging them in the transition to E4H will help to overcome the resistance by those who want to keep the short-term benefits of the current system for themselves.

From the perspective of sustainability, including poverty eradication and equality, humanizing the economy is perhaps the greatest challenge facing the international development community (Restakis, 2010). The efforts focusing on innovations and practices related to public-private partnerships, philanthropy, corporate social responsibility, social impact investment, the promotion of small- and medium-sized enterprises, and integrating small producers in the supply chains of global corporations often result in piecemeal or incremental reforms (Utting, 2013). Exploring ways to implement fundamental transitions is therefore a necessity.

As a consequence of our unparalleled but unsustainable success, there is a need to reconceptualize the purpose of economy. Considering that at any time the flows between human and non-human components of the ELSS take place in the context of the prevailing economic model, we postulate that "a sustainable economy is one that safeguards the Earth's life support system while satisfying the needs of the present and ensuring the well-being of human communities." This definition implies that economy can be sustainable only if it takes responsibility for the health of the ELSS and makes safeguarding the health of ELSS and ensuring the well-being of human communities a dual purpose of economy. Our definition is aligned with that of sustainable development given in Griggs et al. (2013).

"We define a sustainable community as one that satisfies the needs of the present while safeguarding the ELSS on which the welfare of current and future generations depends."

TRANSFORMING THE WORLD BY TRANSFORMING ECONOMY: A PLAN

For civilization to prevail, we need to transition to an Economy for Humanity that sustains and creates thriving communities embedded in a healthy ELSS. E4H (http://economy4humanity.org) aims to initiate this great transition by implementing a pledge for investors, producers, traders, and consumers to participate responsibly in economic activities with the mission to safeguard and restore the life-support system. Based on a holistic measure of the state of humanity and the ELSS, E4H is developing a certification system with comprehensive criteria as a basis on which those participating in economy activities, be it as consumer or producer or trader, can make decisions on which products to produce, trade and consume. The certification system recognizes the degree to which we all live up to this pledge.

The development of criteria and best practices for an E4H supports those who take the pledge. By recognizing and rewarding those who do most to safeguard the ELSS as part of their participation in economy, E4H enables a new economic framework and a societal dialog about an economy for humanity that recognizes the fundamental role of the health of the ELSS for our civilization.

E4H urges all those who partake in the economy, be it as producer, provider, or user, to take a pledge that underlines the dual purpose of economy. At the core of the transition is the certification of producers, traders, investors, and consumers as responsible participants in E4H following up on their pledge. In many societal areas, voluntary and mandatory certifications have proven to be transformational, for example, for safety of work processes and products, the environmental quality of buildings, and to some extent "green businesses." This societal validation of the effectiveness of certification as a means to guide societal development in desired directions provides a solid basis for the approach of E4H.

The approach of medicine to safeguarding the health of individuals and communities has proven to be extremely successful over many centuries. The "Hippocratic Oath" was fundamental for the development of medicine in service to humanity. Applying a similar approach to safeguarding the ELSS by developing a basis for a pledge to an economic practice in service for humanity, with the health of the ELSS being inherent in economy, has very high potential to change the future of humanity and increase the prospects of our civilization.

E4H aims at engaging global expert communities as well as a wide range of NGOs and intergovernmental organizations in the development of a planetary

THE E4H VISION:

To facilitate great transition from the present "economy against humanity" to one for humanity, an economy that meets the needs of the present while safeguarding Earth's life-support system, upon which the welfare of current and future generations depends.

THE PLEDGE:

I will carry out economic activities with the goal of meeting the needs of the present while safeguarding Earth's life-support systems, upon which the welfare of current and future generations depends.

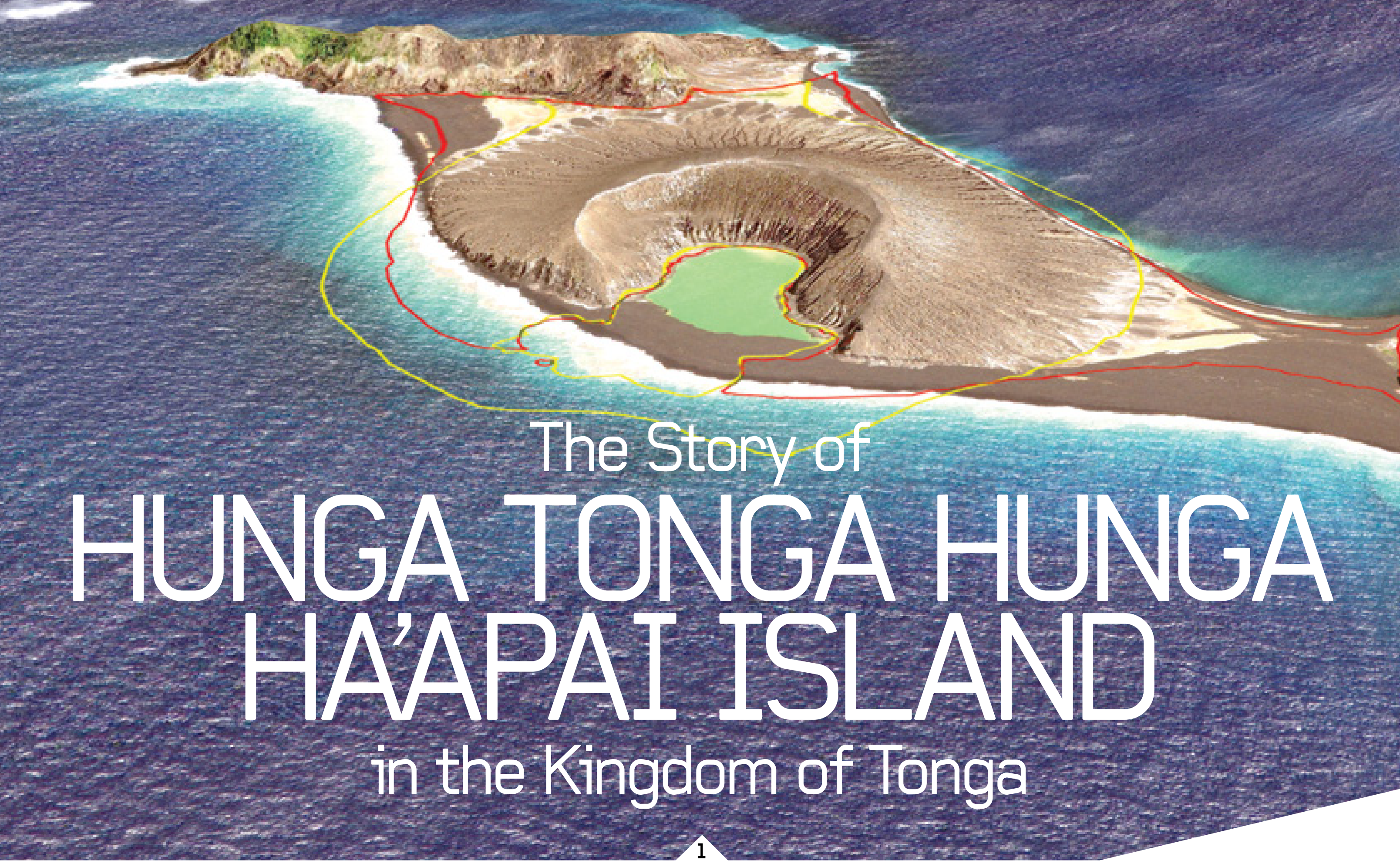
medicine and a laboratory for "patient Earth." The development and validation of a planetary medicine that understands the physiology and processes that maintain a "healthy" ELSS addresses questions including:

- What is the ELSS?
- What are the main physiological processes?
- How does the economic model and its rules impact the human role in, and interaction with, the ELSS?
- What are the vulnerabilities?
- What is the current state and what are the trends?

In addressing these questions, E4H reviews the current ethical, social and economic norms and rules, and identifies core impacts on the ELSS. Realizing that the flows between human communities and the non-human components of the ELSS are controlled by fully mind-dependent ethical, social and economic concepts, rules, and practices, it becomes obvious that we have a mind-based system that is coupled to a mind-independent "real world." It is this understanding of humanity embedded in the ELSS that provides the basis for the approach of E4H: the ethical, social, and economic rules are the "software" or "brain" representing the governance impacting the behavior and development of the "hardware" or "body" that represents the ELSS. By changing the rules and governance, the health of the body can be impacted.

REFERENCES

1. Barnosky, A. D., E. A. Hadly, J. Bascompte, E. L. Berlow, J. H. Brown, M. Fortelius, W. M. Getz, J. Harte, A. Hastings, P. A. Marquet, N. D. Martinez, A. Mooers, P. Roopnarine, G. Vermeij, J. W. Williams, R. Gillespie, J. Kitzes, C. Marshall, N. Matzke, D. P. Mindell, E. Revilla, A. B. Smith, 2012. Approaching a State Shift in Earth's Biosphere. *Nature*, 486, 52-58, doi:10.1038/nature11018.
2. Costanza, R., G. Alperovitz, H. Daly, J. Farley, C. Franco, T. Jackson, I. Kubiszewski, J. Schor, and P. Victor, 2013. Building a Sustainable and Desirable Economy-in-society-in-nature. In The Worldwatch Institute. *State of the World 2013: Is Sustainability Still Possible?* Island Press, Washington, D.C.
3. Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. O'Neill, J. Paruelo, R. Raskin, P. Sutton, and M. van~den Belt, 1997. The Value of the World's Ecosystem Services and Natural Capital, *Nature*, 387, 253-261.
4. Griggs, D., M. Stafford-Smith, O. Gaffney, J. Rockström, M. C. Öhman, P. Shyamsundar, W. Steffen, G. Glaser, N. Kanie, I. Noble, 2013. Sustainable Development Goals for People and Planet. *Nature*, 495, 305-307.
5. Greer, J. M., 2011. The Wealth of Nature - Economics as if Survival Matters. New Society Publisher.
6. Heal, G., 2017. Endangered Economies - How the Neglect of Nature Threatens our Prosperity. Columbia University Press, New York.
7. Jackson, T., 2009. Prosperity Without Growth - Economics for a Finite Planet, Earthscan, New York.
8. Korten, D. C., 2015. Change the Story, Change the Future - A Living Economy for a Living Earth. Berrett-Koehler Publisher.
9. Plag, H.-P., 2015. Finding the Message in the Facts – Has Humanity Evolved into the Most Extreme Hazard, and Anthropogenic Cataclysm? "On The Edge." *Apogeo Spatial*, 30(3), Summer 2015, 8-11.
10. Rieder, T. N. N., 2016. Toward a Small Family Ethics – How Overpopulation and Climate Change are Affecting the Morality of Procreation. Springer International Publishing AG, Switzerland.
11. Restakis, J., 2010. Humanizing the Economy: Co-operatives in the Age of Capital, New Society Publishers, Gabriola Island.
12. Rockström, J., W. Steffen, K. Noone, A. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, J. Foley, 2009. A Safe Operating Space for Humanity, *Nature*, 461, 472-475.
13. Ruggie, J. G., 2003. Taking Embedded Liberalism Global: The Corporate Connection, *Taming Globalization: Frontiers of Governance*, edited by D. Held & M.Koenig-Archibugi, pp. 93-129, Polity Press, Cambridge.
14. Smith, A., 1776. An Inquiry into the Nature and Causes of the Wealth of Nations. Volume 1. W. Strahan, London.
15. Utting, P., 2013. Pathways to Sustainability in a Crisis-ridden World, *Reducing Inequalities: A Sustainable Development Challenge*, edited by G. Remi, R. K. Pachauri, & L. Tubiana, TERI, New Delhi.
16. Utting, P., 2016. Chapter 4, Promoting Social and Solidarity Economy Through Public Policy, *UNRISD Flagship Report 2016: Policy Innovations for Transformative Change -- Implementing the 2030 Agenda for Sustainable Development*, edited by K. Hujo, pp. 115-140, UNRISD, Geneva.



The Story of HUNGA TONGA HUNGA HA'APAI ISLAND in the Kingdom of Tonga

1

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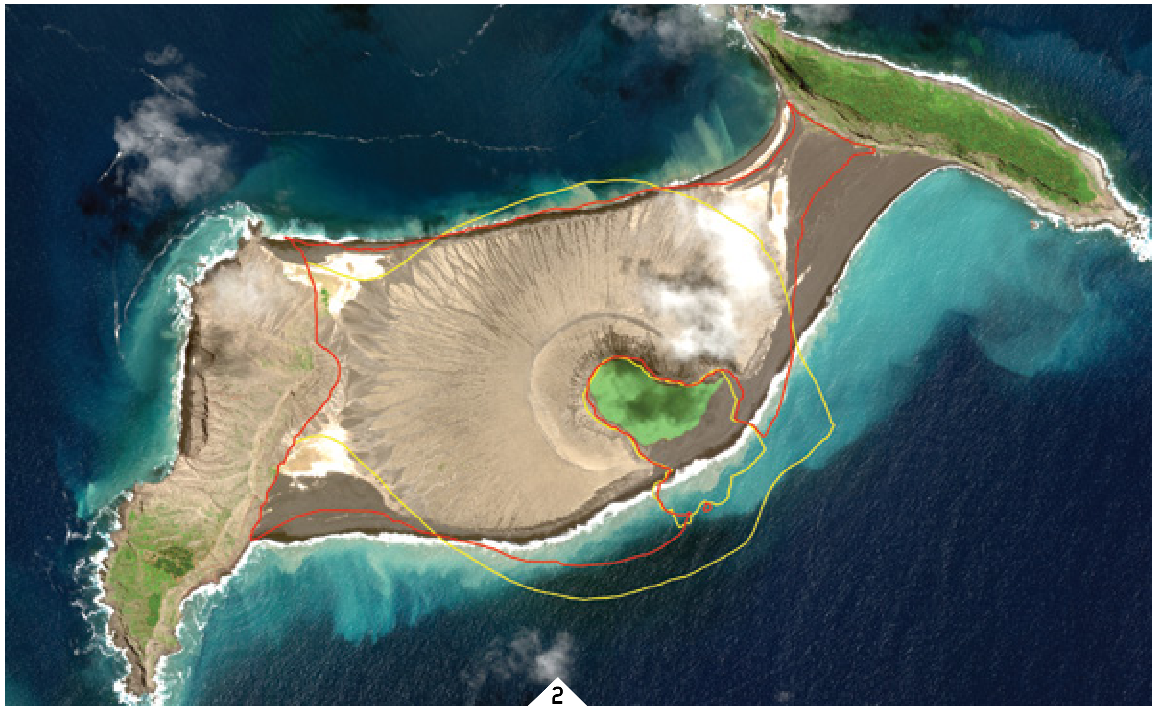
Acknowledgements

This work was supported by NASA Rapid Response and Novel Research in Earth Science (RRNES) grant number RRNES-20 (NASA HQ Earth Sciences Division, c/o Dr. Jack Kaye) and via a cooperative research partnership with the Canadian Space Agency (CSA) and MacDonald, Dettwiler and Assoc., Ltd. (MDA). Radarsat data and products courtesy of MDA (2017) - All rights reserved. Radarsat is an official trademark of the CSA. The team at the National Geospatial-Intelligence Agency under Chalbeth Reynolds, Robert Quest Brannock, and Steve Hopkins were extraordinarily cooperative in providing critical DEM products as part of our time series of observations, including the DigitalGlobe images. The assistance and patience of the USGS CRSPP team, including Brenda Ellis and James Hak, was instrumental for obtaining the frequent DigitalGlobe WorldView acquisitions. Finally we dedicate this work to the memory of Professor Gunter Menz of the University of Bonn who was involved in an earlier component of this work.

▲ **FIGURE 1.**
DigitalGlobe WorldView-2 image (Sept. 2, 2016) ray-traced atop a DEM produced on the basis of WorldView satellite stereo images from Aug-Sept. 2016 (by NGA) illustrates the evolution of the HTHH island from birth (yellow outline of coastline) to present status. This view is from the southeast looking across the new island (HTHH) with the pre-existing islands of Hunga Tonga (right side) and Hunga Ha'apai (upper left) shown. Image courtesy NGA.



▲ FIGURE 2. DigitalGlobe WorldView-2 image of HTHH from January 15, 2017 with superimposed coastline boundaries. Shown in yellow is the outline of the original island just after the end of volcanic construction in January 2015. The red outline is the coastline geometry as of early 2016. The development of accreted sandy isthmus regions to the northeast and west of the core of the new island is apparent. Courtesy NGA.

SUMMARY

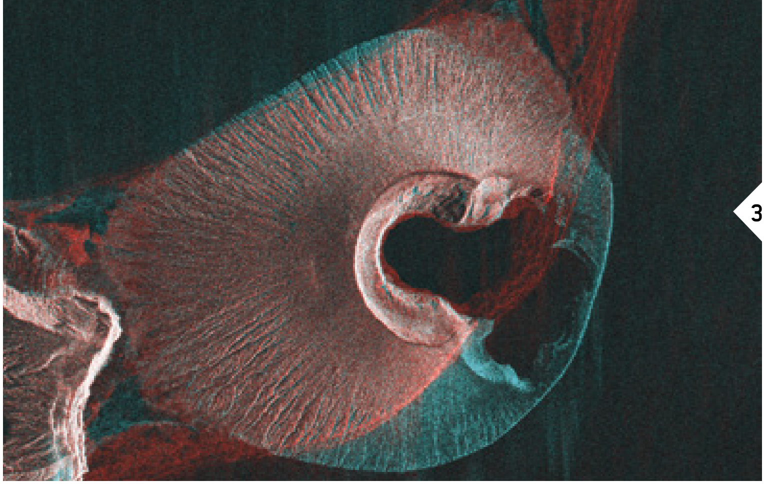
An explosive submarine volcanic eruption produced a new ~ 1.9 square kilometer island in the southwestern Pacific Ocean in the Kingdom of Tonga between mid-December 2014 and the end of January 2015. The ~ 150 meter tall volcanic island, hereafter referred to as Hunga Tonga Hunga Ha'apai (HTHH), was formed by hydrovolcanic eruption processes leading to the construction of a classical tephra cone volcano with flank pyroclastic flows. High resolution satellite imaging began just after the end of the construction phase using the DigitalGlobe WorldView system, and shortly thereafter with the Canadian Space Agency's (CSA) Radarsat-2 C-band Synthetic Aperture Radar (SAR). Digital Elevation Models (DEM) were produced periodically by the National Geospatial-Intelligence Agency (NGA) using Worldview images in a time series that began in May of 2015.

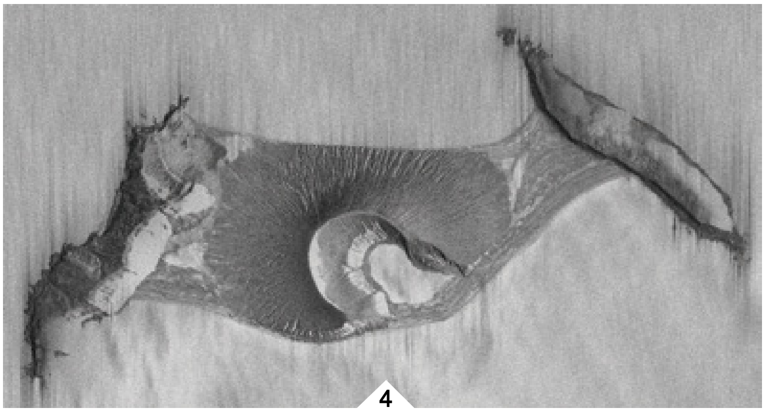
The rapid landscape evolution of a newly-formed volcanic island offered the first-ever opportunity to use entirely satellite-based observations to quantify erosion due to marine abrasion, mass-wasting, and subsidence at heretofore unavailable spatial scales (< 1m). Comparisons of the continuing evolution of the new Tongan island with the Icelandic type-locality for such submarine eruptions (Surtsey) illustrate differences potentially due to the composition of the explosive ash and to a general absence of erupted lavas at HTHH. In addition, differences in the rates of erosion at HTHH and Surtsey near Iceland in comparison with similar-appearing landforms on the planet Mars permit assessment of the volcanoes on other worlds where erosion is likely to have operated as a function of past environmental conditions.

On the basis of two years of satellite observations in three-dimensional context, the anticipated lifetime of the new island in Tonga is likely to be on the order of ~10 years, although a low-relief isthmus in the vicinity where the new island formed could persist for decades. This NASA and CSA-supported study showcases the potential for quantifying the evolution of Earth's most dynamic landscapes from meter-resolution satellite remote sensing capabilities that now offer both scientific and societal benefits.

INTRODUCTION

The opportunity to develop both high spatial and temporal resolution observations of terrestrial landscape systems from their time of origin to their demise has typically required episodic aircraft and field-based campaigns with a resulting lack of temporal continuity. For new volcanic islands in remote oceanic settings, the best-studied example is Surtsey,[1,2] which is located off the southwestern coast of Iceland, and whose evolution after the 1963-67 eruption was carefully documented using systematic aerial photography and topographic mapping. The results have characterized the continuing evolution of Surtsey as a benchmark landscape





▲ **FIGURE 3.**
Overlay of CSA Radarsat-2 Spotlight SAR images (SLA19 geometry) from March 16, 2015 in blue and the current island expression as of March 5, 2017 in red. The large isthmus to the northeast is made up of re-deposited (accreted) sediments derived from the erosion of the southern coastal region. Twenty individual time-steps in this geometry over the past two years have been acquired at heretofore unavailable scales independent of cloud-cover or solar illumination. Courtesy MDA and the CSA Radarsat-2 Background Mission.

▲ **FIGURE 4.**
CSA Radarsat-2 SAR (SLA21 mode) image from March 11, 2017 shown as inverted total backscatter to emphasize the stratigraphy of the erosional patterns at the island. Inner crater mass-wasting and isthmus strandline depositional processes are evident. Images such as this have been acquired every 24 days since March of 2015 by the CSA Radarsat-2 Background Mission as part of research activities to document the evolution of small, sensitive oceanic islands as "barometers" for global change signatures. North is to the upper right and the field of view is 2 km across. Image courtesy MDA and CSA.

system[1] of relevance to other recently formed islands and also applicable to landscapes on the planet Mars.[3]

The birth of a new island in the southwestern Pacific Ocean around Dec. 19, 2014 via tephra-dominated hydro-magmatic processes (Surtseyan-style) was witnessed by NASA's Earth Observing System sensors during the course of its month-long construction phase. Such eruptions are not uncommon in this region and similar events occurred in 2008-2009 with ephemeral island formation and subsequent destruction over a period of months.[4] The opportunity to take advantage of newly-available satellite-based imaging systems at both optical and microwave (C-band SAR) wavelengths with meter resolution presented itself as a worthwhile demonstration of space-based landscape monitoring techniques at new temporal and spatial scales (***Figure 1***).

A systematic campaign for coordinated satellite observations was developed for the purpose of quantifying the erosional rates and processes for the new island in comparison with current understanding of the evolutionary sequence for typical oceanic islands.[5] Monthly optical satellite images from DigitalGlobe's WorldView imaging system were arranged via the U.S. Geological Survey's Commercial Remote Sensing Space Policy (CRSSP) program. Acquisition of Radarsat-2 SAR images in two independent viewing geometries every 24 days was arranged in cooperation with the CSA Radarsat-2 Background Mission. As part of this study, observations have been systematically collected since March 2015, and it is anticipated that monthly collections will continue. Ship-based observations were also coordinated on the basis of initial results and the Schmidt Ocean Institute (SOI) Research Vessel Falkor measured deep water bathymetry around HTHH in Spring of 2016.

In this article, we focus on the subaerial expression of the island, its coastline evolution, the rate of change of the volume of the central tephra cone, and its projected lifetime as a benchmark system within the southwestern Pacific Ocean. The application of results achieved for HTHH for small hydro-magmatic volcanoes on Mars is also considered.

APPROACH

Time series of DigitalGlobe WorldView-1, 2, 3 optical and CSA Radarsat-2 Spotlight SAR images were acquired, when possible, starting in March 2015 through March 2017, covering more than two years in the life of the Tongan island. NGA-developed Digital Elevation Models from the WorldView images were provided in multiple time intervals, including May 2015 and August/Sept. 2016. Ancillary data from the German Space Agency (DLR) TanDEM-X SAR System have been folded into the preliminary assessments conducted thus far as well.

In the first few months after island formation, rapid erosion of the southern coastal region resulted in loss of ~ 5% of the island's initial volume, with redistribution of the derived sediments to form a connecting isthmus to the northeast with the pre-existing Hunga Tonga island. The intensity of marine abrasion from the south attacked the weakly indurated tephra that formed the southern rim of the interior crater, leading to its collapse by May 2015, and promoting re-deposition of the eroded materials to the northeast. Coastline changes documented from the integration of WorldView images (***Figure 2***) with NGA digital topography and Radarsat-2 SAR (***Figures 3, 4***) documented the evolutionary pathways established at this time. On the basis of recent experience[4] it was not anticipated that the initial HTHH island would survive as a discrete subaerial volcano for more than several months.

Isthmus sediments developed ~ 2m thick between May 2015 and March of 2017 to the northeast, as clearly delineated in the Radarsat-2 SAR backscatter images. ***Figure 3*** illustrates these deposits in a comparison of the initial topology of the island (March 16, 2015) and by means of its current landscape configuration (March 5, 2017). The accretion of eroded sediments to form a widening isthmus to the northeast with growing relief (***Figure 3***) may help to stabilize a portion of the new island for longer-term survival.

The topographic evolution of the island is of particular interest because it is intimately linked to overall island survival within the classical evolutionary sequence outlined in the scientific literature.[2,5] On the basis of multiple DEM time-steps starting around May 1, 2015 and extending to September 2016, we have witnessed the general decay of the central core of the island from an initial post-eruptive volume of 0.070 cubic km to its current state at ~ 0.053 cubic km. At this rate of primary "core" island loss, the survival of the main edifice beyond ~10 years is not assured.

ANALYSIS

After more than two years of satellite high-resolution monitoring of Earth's newest land, the pace of erosion appears to have temporarily slowed. While continued wave attack from the southeast remains in effect, leading to pulses of deposition to the northeast, the general island outline and its isthmus deposits has remained relatively constant for multiple months. Evidence of inner crater wall mass-wasting and development of a sediment bench region is now apparent in the most recent CSA Radarsat-2 SAR images (***Figure 4***).

Such SAR images are particularly effective when processed with their total backscatter inverted so that they appear as "shaded relief" style maps. Our work with SAR and optical images registered to the NGA-developed DEMs has documented the rates of erosion under the geologic and environmental conditions in the southwestern Pacific.

Whether HTHH survives as a volcanic edifice for decades as Surtsey has since its period of formation in the 1960's will depend on development of internal stabilization via palagonitization[2] or other processes which cement friable volcanic ash into mechanically stronger materials. By continuing to measure both topographic and spatial changes at HTHH as a benchmark oceanic volcanic island, we anticipate the telltale signatures of the next pulse of large-scale erosional adjustments will be detectable and therefore quantifiable.

CONCLUSION

It is now possible to quantify the evolution of dynamic landscape systems from their time of formation until they are little more than relicts. We have estimated the lifetime of the central core of the new volcanic edifice as ~ 10 years if current rates of erosion continue over the next few years.

On the basis of the rates of landscape evolution at HTHH in comparison with Surtsey, we can now examine the likely timelines for evolution of small kilometer-scale hydro-volcanic edifices in the northern plains of Mars. This work supports the current models developed within the Mars scientific community[3] that many of these small edifices formed rapidly, only to degrade very slowly over geologic time-scales. Future Mars missions will test the idea that some of the Martian analogues to island volcanoes may have formed rapidly and then eroded due to hydrologic processes at rates that no longer exist today on the Red Planet.

Endnotes:

1. Garvin, J. B., R. S. Williams, Jr., J. J. Frawley, W. B. Krabill (2000): Volumetric evolution of Surtsey, Iceland, from topographic maps and scanning airborne laser altimetry, Surtsey Research 11, 127-134.
2. Wohletz, K. and M. Sheridan (1983): Hydrovolcanic Explosions II: Evolution of Basaltic Tuff Rings and Tuff Cones, *American Journal of Science*, Volume 283 (May 1983), p. 385-415.
3. Broz, P. and E. Hauber (2013): Hydrovolcanic tuff rings and cones as indicators of phreatomagmatic explosive eruptions on Mars, *Journal of Geophysical Research: Planets*, Vol. 118, 1656–1675, doi:10.1002/jgre.20120, 2013.
4. Vaughan, R.G. and P. Webley (2010): Satellite observations of a Surtseyan eruption: Hunga Ha'apai, Tonga, *Journal of Volcanology and Geothermal Research*. 12/2010; 198(1-2):177-186. DOI: 10.1016/j.jvolgeores.2010.08.017.
5. Nunn, P. (1994): *Oceanic Islands* (Natural Environment), Wiley-Blackwell Press, London, 360 pages.

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