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ELEVATING GLOBAL AWARENESS

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Image of ocean floor courtesy of XPRIZE.


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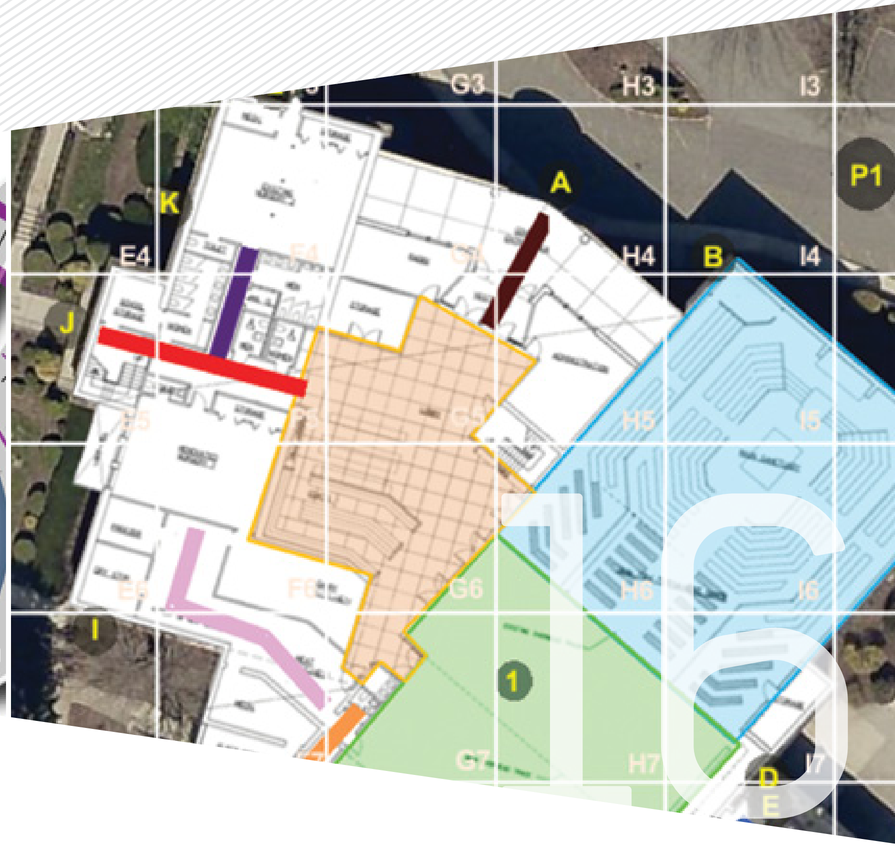

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COVER IMAGE

The Ocean Floor

MAPPING THE OCEAN FLOOR has yet to be done. The XPRIZE Foundation's newest prize is the Shell Ocean Discovery XPRIZE, which will inspire innovation, and eventually result with exactly that. The award is $7 million to the winners, to be announced in December 2018.

This image is courtesy of XPRIZE. The article about the Shell Ocean Discovery XPRIZE is on page 8.

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Formerly Imaging Notes

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MISSION

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

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STAFF

Publisher/Managing Editor **MYRNA JAMES YOO**
myrna@apogeospatial.com

Editor **RAY A. WILLIAMSON, PhD**

Contributing Writers **LEONARD DAVID**
MATTEO LUCCIO

Creative Director **ANDREW STERNARD**
www.andrewsternard.com

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SPATIAL
ELEVATING GLOBAL AWARENESS

Achieving the SDGs, and the XPRIZE

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

DEAR READER,

Rarely do contests capture people's imagination in the way that the XPRIZE does. I remember learning about the 2007 $30 million Google Lunar XPRIZE, a competition that challenges innovators and entrepreneurs to develop methods of robotic lunar exploration. Currently, 16 teams are still working toward getting their robots to the moon by the December 2017 deadline, and accomplishing the goals of the project.

The XPRIZE Foundation is currently executing the Shell Ocean Discovery XPRIZE, which is $7 million to those who will map the ocean floor. The article is on page 8.

This week, I attended SciDataCon 2016, as part of International Data Week. Several sessions covered Earth science data, and the applicability of Earth science and geospatial tools to reaching the 17 Sustainable Development Goals (SDGs) of the United Nations (UN) Agenda 2030.

The SDGs are very broad, and encompass almost every aspect of humankind, which I find to be quite ambitious and exciting. Many scientists, volunteers, and executives are working towards attaining such things as No Poverty; Zero Hunger; Clean Water; Reduced Inequalities; and Peace, Justice and Strong Institutions, worldwide, to name a few.

There is no question that achieving these goals will be complex. Many organizations and stakeholders are coming together to find ways to do so. The power of geospatial tools in addressing many of them is generally accepted now, following the evangelizing of many stakeholders.

Will Marshall, CEO/co-founder of Planet (formerly Planet Labs) spoke last year at the UN in New York City about how geospatial data and in particular satellite imagery will be crucial to achieving the Millennium Development Goals (the original set of goals that are the foundation for the SDGs). In addition, a new white paper has been published by *Geospatial Media* with sponsorship by DigitalGlobe on the same subject, "Transforming Our World: Geospatial Information – Key to Achieving the 2030 Agenda for Sustainable Development."

On page 24, we share two possible approaches to looking at these goals, due to their complexity and overlapping nature, including Agent-Based Models and GeoDesign. The former is used as an example of how to approach addressing Gender Equality (Goal 5) and the latter to address Sustainable Human Settlements (Goal 11).

It would appear that the global Earth science community is finally coming together in very important new ways to share not only data but solutions. The Belmont Forum is a consortium of the top 21 funders of environmental science that will contribute to delivering the knowledge needed for action. The Belmont Forum plan was adopted in October 2015, and will continue to fund peer-reviewed research, with a stronger emphasis on data sharing, not just data.

I hope that this and many other efforts will create more repositories of data and break down more silos, so that different organizations are not duplicating efforts and so that efforts to create a truly sustainable world can move forward.

The value of geospatial tools and data continues to grow, and now, accessing that data and finding answers is easier and possible in more ways than ever before. To achieve this, most geospatial companies are developing platforms, with various and similar datasets. The most innovative are ingesting new dynamic datasets, such as wide area motion imagery, traffic, and weather, which are some of the most real-time hyper-local datasets that exist.

Dynamic datasets can be ingested into many of these platforms, including PIXIA's and Luciad's. Our ongoing series on "Filling the Gap" (that will be left by Google Earth Enterprise) includes in this issue both of these companies, as well as BAE Systems, and begins on page 16.

Obviously, the commercial platforms are offering solutions to problems. In order to meet the SDGs, the private and public sectors should join together. Addressing the UN SDGs are what this publication is all about: sharing information about solving the world's biggest, most complex, problems using geospatial technologies.

Thanks for reading.

Robots of

XPRIZE and Shell Enable Mapping of the Sea Floor

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

XPRIZE LIST

- $30M Google Lunar XPRIZE
- $20M NRG COSIA Carbon XPRIZE
- $15M Global Learning XPRIZE
- $10M Qualcomm Tricorder XPRIZE
- $7M Shell Ocean Discovery XPRIZE
- $7M Adult Literacy XPRIZE
- $5 IBM Watson A.I. XPRIZE

the Deep

We have mapped the surface of the Moon at a resolution of 328 feet. We have mapped the surface of Mars. Yet, here on Earth, 95 percent of the deep seas remain a mystery to us. Put another way, that's two thirds of the entire solid surface of the planet. The health of the oceans is critical to our species' survival, because of its role in climate change, as a source of food, and as a potential source of energy.

The XPRIZE Oceans Initiative aims to put us "on an unstoppable path toward healthy, valued, and understood oceans," says Jyotika Virmani, Senior Director for Prize Operations at XPRIZE. The organization is a non-profit headquartered in Los Angeles that awards cash prizes in the millions of dollars to teams that develop innovative solutions to some of the greatest challenges facing humanity, in five areas: exploration, global development, energy and environment, learning, and life sciences.

JYOTIKA VIRMANI, PHD

The goal of the first XPRIZE, launched in 1996, was to kick-start the private space flight industry. The foundation is currently operating seven XPRIZE competitions, including the $30,000,000 Google Lunar XPRIZE, with the goal of launching a robot to the Moon that will traverse 500 meters and return video and photography images from the Moon. The long-term goal of this prize is to develop the technology that we will need as humanity to move off of Earth. The other prizes are listed on page 8.

THE OCEANS INITIATIVE

The Oceans Initiative is a commitment that XPRIZE made to launch five ocean prizes over the space of ten years, designed to raise awareness of the grand challenges facing our oceans, encourage a diverse community of international ocean partners to tackle them, and catalyze sustainable markets and industries. The first one was for oil clean-up technology, following the oil spill in the Gulf of Mexico. The second one was to develop pH sensors to measure the changes that are happening in the oceans as a result of climate change. According to XPRIZE, the first two prizes in this initiative have already led to an exponential increase in ocean technologies, sensor companies and products, and new careers in ocean engineering for a fraction of the price compared to traditional funding for research and development.

The current and third competition in the initiative, the Shell Ocean Discovery XPRIZE, is a $7,000,000, three-year competition to incentivize teams to develop robots to map the ocean floor and return high definition imagery from the deep sea. The National Oceanic and Atmospheric Administration will award a $1,000,000 bonus prize to develop pioneering technology for detecting and tracking biological and chemical signals under water back to their source. The competition currently has 22 teams, representing more than ten countries. The winners will be announced toward the end of 2018.

According to XPRIZE, by accelerating innovation for the rapid and unmanned exploration of the unchartered deep sea, this prize will "catalyze markets in deep ocean exploration, sustainable resource development and protection" and solutions "will provide a pathway for discovering new species and underwater life forms, along with safer methods of exploring this challenging environment." Additionally, "this competition will ignite the public's imagination by shedding a long overdue light on the most mysterious place on Earth."

Getting to the Bottom of Our Ocean.

The Shell Ocean Discovery XPRIZE (OceanDiscovery.xprize.org) is a global competition challenging teams to advance deep-sea technologies to allow for autonomous, high-speed, and high-resolution ocean exploration. As part of the competition, the National Oceanic and Atmospheric Administration (NOAA) will award a bonus prize to incentivize teams to develop technologies to detect the source of chemical and biological signals under water.

The $7 million prize purse will be awarded as follows:

- *Grand Prize: $4 million*
- *Second Prize: $1 million*
- *Milestone Prize: $1 million will be split among the top (up to) 10 teams from Round 1*
- *NOAA Bonus Prize: $1 million will be awarded in Round 1 to the team that successfully detects and identifies a biological and chemical signal*

The three-year competition was launched in December 2015 and will proceed according to the following timeline:

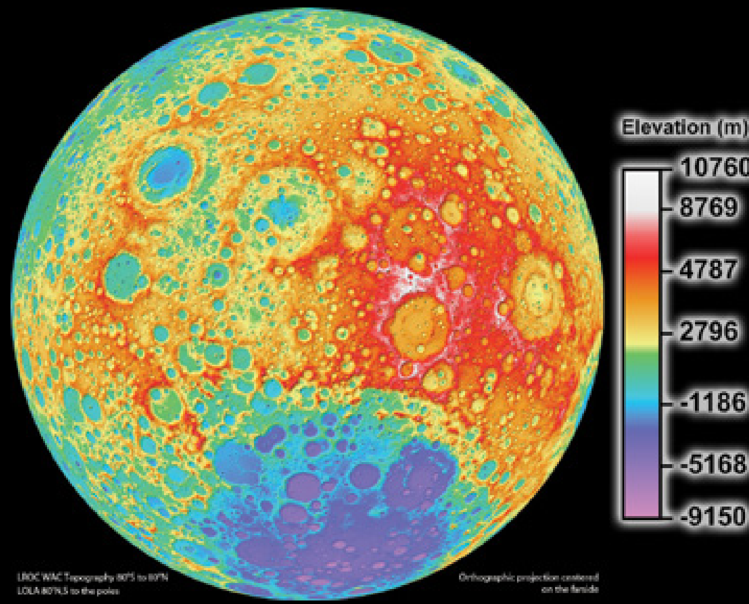
- *Team Recruitment: December 2015 - September 2016*
- *Team Registration Deadline: Sept. 30, 2016*
- *Round 1: October 2016 - December 2017*
- *Round 2: January 2018 - November 2018*
- *Winners Announced: December 2018*

Specifically, the competition aims to advance deep-sea technologies to allow for autonomous, high-speed, and high-resolution ocean exploration. In the first round, teams must map at least 20 percent of a 500 km^2 area at 2,000 meters depth at a resolution of 5 meters or higher within 16 hours, and produce a bathymetric map, a high-definition photograph of a specifically named target, and five high-definition photographs identifying archeological, biological and/or geological features. To win the bonus prize, teams will detect the point of origin of a specifically selected chemical and biological signal underwater. In the second round, teams must map at least 50 percent of a 500 km^2 area at 4,000 meters depth at a resolution of 5 meters or higher within 24 hours, and produce the same deliverables as in the first round, except for ten photographs rather than five.

To view the sea floor maps that the teams produce, XPRIZE is partnering with Esri. The company is donating its ArcGIS Online software to competing teams who will submit their maps for judging via the platform. Esri will also create a Story Map of the competition, allowing everyone to follow the teams' deep-sea adventures.

A Story Map is Esri's medium for sharing data, photos, videos, sounds, and maps, and for using that content to tell a compelling story. This is all done with sophisticated cartographic functionality that does not require advanced training in cartography or GIS.

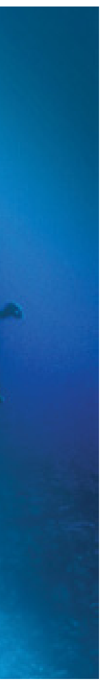
> "The first two prizes in this initiative have already led to an exponential increase in ocean technologies, sensor companies and products, and new careers in ocean engineering."



▲ **FIGURE 1.** NASA's Lunar Reconnaissance Orbiter (LRO) topographic map of the moon was created with LRO's Wide Angle Camera and the Lunar Orbiter Laser Altimeter in 2011. The moon is mapped to a pixel scale of close to 328 feet.

FUTURE APPLICATIONS

Virmani has a master's degree in atmospheric science and a Ph.D. in physical oceanography, the latter based mostly on her work with sensors at sea. Her expertise in weather, climate change, tropical storms, and hurricanes brought her to XPRIZE as the technical director of the Ocean Health Competition, which focused on the challenges associated with sensors at sea. After that prize was awarded, last summer, she took on the role as the Senior Director in the Prize Operations group at XPRIZE and became the prize lead for the Shell Ocean Discovery XPRIZE.



The entire deep sea floor has been mapped to around 5 kilometers resolution and about 10 percent has been mapped to a higher resolution. "The maps that we generally see are essentially interpolations," Virmani points out, "so they are not based on measurements. A map is a fundamental piece of understanding any environment and that is what this prize is really tackling."

"In the short term," Virmani explains, "we want to achieve three impacts: to accelerate technology, catalyze new markets—including markets in deep sea conservation and management, potentially eco-tourism—and mapping the entire deep sea floor. We also want to inspire the public, because, essentially, we are living on an unexplored planet. In the longer term, the goal is that the technologies will help to map the entire sea floor at a high resolution by around 2030."

This is in alignment with the road map for the future of ocean floor mapping issued by the General Bathymetric Chart of the Oceans, an international non-profit organization of geoscientists and hydrographers that aims to provide the most authoritative publicly-available bathymetry of the world's oceans.

"The technologies that will come out of the Shell Ocean Discovery XPRIZE in the future can be used for searching for planes that go down or for geothermal vents or biological hot spots," says Virmani. "All the technology will be deployed from the shore or by aerial drones. We did this because one of the market failures that we identified through this competition and the reason that the deep sea floor has not been mapped is that it is really expensive to have ships that have to sail for ten days before you get to the location, when it costs $60,000 per day."

For the past 4,000 years, our technology for mapping the sea floor consisted of dropping a weight at the end of a line and measuring how far it had gone when it hit the bottom. Only in the last hundred or so years technology has allowed us to make these maps through an opaque environment. "With the exponential growth in such technologies as 3D printing, artificial intelligence, and robotics," Virmani says, "how can we pull in some of those cutting edge changes to help us to map the deep sea floor? There are now drones that can go from the air to underwater. Why can we not use them for mapping the ocean?"

The convergence of all these new technologies combined with the talented and ambitious teams will result in some incredible leaps forward for oceanographers, with benefits for all of humankind. ∧♂

ON THE EDGE

A Look at Earth from Aliens' Perspective

THE POWER OF UNCONSCIOUS BIASES

Prof. Hans-Peter Plag, PhD
Mitigation and Adaptation Research Institute
Old Dominion University
Norfolk, Va.
www.mari-odu.org

THE UNSEEN PATTERNS IN HUMAN BEHAVIOR ARE not only among the causes for racism, they also cause misinterpretation of evidence and prevent the creation and use of knowledge.

Looking at the current trends in the Earth system and the dominant role of humanity in causing these trends is alarming and should lead to immediate action. In earlier columns I pointed out that humanity has evolved into the "Anthropogenic Cataclysmic Virus" in the Earth's life-support system: our global energy usage of about 18 Terawatts is comparable to a large volcanic eruption (like the eruption of Mount Tambora in 1815) every few years. The high extinction rate is destabilizing ecosystems globally.

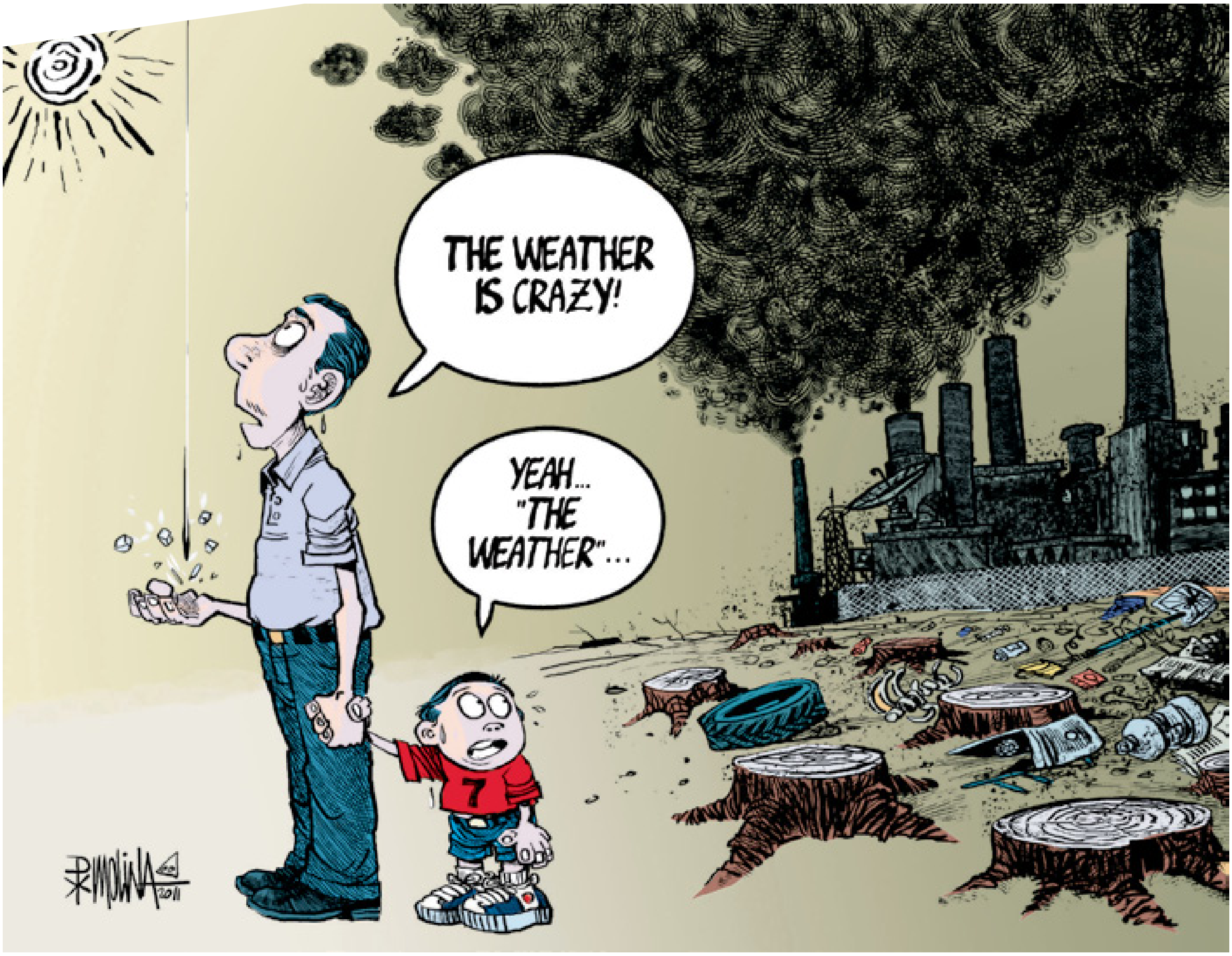
Feeding the people from the population explosion required a fundamental and unsustainable re-engineering of the nitrogen and phosphorous cycle. Energy dissipation from fossil fuel deposits through humanity's metabolism into the environment and the changes in the chemical composition of the atmosphere and the albedo of the Earth's surface cause a rapid warming of atmosphere and ocean comparable to 5,400 billion 60 Watt light bulbs running continuously[1] – roughly a light bulb on every 100 square meters everywhere on the Earth's surface (more than 70 light bulbs on a standard soccer field!).

The additional energy stored in the Earth's system of 320 Terawatts is about 18 times the energy actually used by humanity: the systemic changes caused by a rapidly growing population have a large "side effect." Foresight tells us that a high-energy planet will be dynamically very different from what humanity has experienced throughout the Holocene: extremes like heat waves, storms, floods, droughts and wildfires (which are already now causing increasing loss of life and property) will render much of the planet's land surface uninhabitable for humans and make life very difficult in the near future for those populating the Earth today and in the future. The facts are clear and the narrowing spectrum of possible and somewhat post-apocalyptic futures is frightening.

Any intelligent species with an honest desire to avoid extinction would use these facts to initiate immediate actions to transform the way we build, produce, consume, fight each other, and handle our waste. An intelligent species would understand that the rapid growth of energy use (from population of about 1.65 billion in 1900 to 7.45 billion today[2]) facilitated by virtually unlimited access to energy, is the underlying cause and would stop growth immediately. I wholeheartedly agree with Travis Rieder that it has become morally and ethically difficult to justify having more than one child: As he puts it, "It's not the childless who must justify their lifestyle. It's the rest of us."[3]

However, all this evidence and the foresight of where we are heading is not triggering the necessary decisions to avoid a post-apocalyptic future. Why is this so? Are we smart enough to create the knowledge of what is happening and why, but not intelligent enough to use the knowledge? Decisions made by human beings are not solely based on fact and rational considerations; they are heavily impacted by a number of cognitive biases.[4] Importantly, the Blind-spot Bias keeps us from realizing our own biases and their severe impacts on our decisions.

Just to name a few, the Outcome Bias leads us to overvalue a positive outcome: the fact that past economic growth had many positive aspects



▲ FIGURE 1. By Pedro X. Molina, printed with permission of Cartoon Movement

doesn't mean that aiming for more economic growth without having a perspective for prosperity without growth will lead to a sustainable future.

Our Overconfidence Bias lets us believe that somehow we, or someone, will find a solution without us having to do much. The Conservatism Bias (or Normalcy Bias) leads us to favor prior evidence over new evidence: the fact that climate has been extremely stable with only minuscule variations throughout the Holocene makes it difficult for us to accept the overwhelming evidence that this time of stability has come to an end.

As a result of the Bandwagon Effect, the probability of an individual adopting a belief increases with the number of people holding this belief. The Confirmation Bias makes us more open to information that confirms our preconceptions and leads many of us to ignore information that contradicts them. Not least, the Ostrich Effect keeps so many of us from seeing the evidence and accepting the even more frightening outlook for our future, if we don't act immediately.

Understanding the importance of overcoming the Blind-spot Bias, I developed with my colleague Michelle Heart in the English Department at my university, a course on "Decisions, Biases, and the Creation of Knowledge." The course addresses the full spectrum of biases at individual, group, country, and cultural levels, and their impacts on the perception of evidence and risks and the decisions made to address threats. It was enlightening to watch how the reflective approach changed the students' understanding of the impacts of biases and the creation and use of knowledge, and enabled them to extract the story embedded in the scientific evidence concerning our future on a degrading planet.

For the last of three essays, the students had to define themselves as aliens from another planet visiting Planet Earth with the mission of finding out whether there is "intelligent life" on Earth. It was a pleasure for us to read these essays. The one by Katie Anderson titled "My Visit to the Blue Planet" was particularly to the point and "entertaining," although the final decision of the aliens' delegation was not what humans might want to see as the result of such a visit. With her permission, here are portions of her essay. (The full essay is available online at www.apogeospatial.com/a-look-at-earth-from-aliens-perspective).

MY VISIT TO THE BLUE PLANET

I journeyed far to find this place; my species has long suspected that there were intelligent life forms out in the universe, and I was among the delegation selected through a complex process to be sent to the Blue Planet we believed most likely to sustain life. Among the qualifications I possess, along with the other 19 members of our crew, are the ability to make decisions grounded in fact and research, the belief that all organisms are equally worthy of respect and recognition, and the drive to attain greater knowledge for the advancement of our planet's understanding of the world. Like everyone on my planet, all members of the delegation are required to understand the complex interplay of all systems – organic and inorganic – and pledge our lives to the good of all.

We were given two clear objectives on our journey: 1) to determine if the planet contains intelligent life forms, and 2) to determine if a long-term relationship between our planet and the Blue Planet could be sustainable. Following is what I encountered in my two-year stay on the Blue Planet, which I will here explain as well as my team's findings on these two concerns...

When our team arrived, we landed safely in what appeared to be uninhabited land except for a few large, inorganic looking contraptions. We stepped out onto a rather barren land; the up and down motion of the contraptions captivated us, but it disturbed me greatly. For what purpose were these machines placed here, seemingly unsupervised? The heat of the place almost suffocated me… We quickly learned that the life forms on this planet (humans) are fearful of strangers, and rather than get to know the new entity first as we would do on our home planet, their fear caused them to shackle our arms, point large weapons at us, and move us to secure lodgings rather abruptly. We were moved in large vehicles with metal shells and windows propelled with clunky motors that I noticed emitted a gas into the air behind us as we moved along the path…

Our first goal was to learn about the planet; our second was to explore the ways in which the humans interacted with the planet; our third was to discern clear answers to our two points of charge: are they intelligent and is it worth cultivating a diplomatic relationship with the planet?

Humans seem dedicated to understanding the life on their planet; they are desperately trying to account for all the life on the Earth. We learned, however, that part of their frenetic search for new species is a clear fear that many of them are soon to disappear. This leads me to our second discovery.

Humans are killing the life support systems on their planet at an alarmingly rapid rate. Estimates suggest that already a third of the species of animals living on the planet have become extinct…

We wondered: do the humans know what they are doing to the Earth? We read time and again about the impact of the economic practices, production practices, and lifestyle choices upon the globe, yet we saw very few instances of countries where humans were working to mitigate the coming disaster. In fact, what we saw was an abundance of information regarding the production of more and more consumer products for western markets.

RESULTS REGARDING INTELLIGENT LIFE ON EARTH

We read time and again concerning reports on the status of the Earth, dating *back nearly half a century, yet these humans refused to act upon their knowledge. In fact, knowledge was viewed skeptically by many, and humans continued to make decisions with bias and not fact, rarely stopping to communicate with better-educated humans to ensure their decisions were the best for the broadest group of humans. We desperately wanted to believe that these creatures, capable in some instances of compassion and empathy, were intelligent, but as a result of their failure to act upon knowledge, and in many instances acting in direct opposition to their knowledge, we had to rule that they were unintelligent creatures. This lack of intelligence will lead to the ultimate ruination of the Earth, a planet that will have to rebuild itself, likely without humans upon it.*

RESULTS REGARDING CONTINUING A RELATIONSHIP WITH EARTH

This answer came to us quickly. After reading about the way in which the governments of the countries on Earth operate, we decided that a long-term relationship with these people was not possible. They are inclined to use situations to their advantage alone without considering the impact upon others. If given an opportunity to open up regular intercommunication, we feel that the humans would soon use our planet as a colonizing location, which we know to be populated to capacity in a sustainable way. If they were to come to use (and likely abuse) our resources, our planet would soon face the same devastation of the one they currently inhabit.

While we are grateful to the humans on the Earth for their assistance in our mission, we feel as though theirs is a population doomed as a result of its own inability to use facts as a primary source of decision making in addition to a failure to see all human life as worthy of consideration and protection. We hope they mitigate their impending disaster, but we have little hope for them.

It may be a long time until aliens will visit us here on the Blue Planet, and by that time, they may find remnants of an obviously highly developed species – and, if they are like the aliens in the essay biased towards rational and evidence-based decisions, they may wonder why a species that reached such a high technological level and left a clear geological signal of a distinct epoch on the planet obviously went extinct very rapidly. They wouldn't know, though, that we called this epoch the Anthropocene. Or, we finally might realize that our addiction to unlimited growth is suicidal and transform into the planetary stewards we need to be if we want our species to be around much longer. I am sure, in this case, alien visitors would come to a very different conclusion.

Maybe we won't have to wait that long for such visitors: It seems like we just discovered the "Earth Next Door," an exoplanet called Proxima Centauri b, only four light-years away from us that holds the promise of being very much like our planet.[6] ∧♂

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Geospatial Solutions from Pixia, Luciad, and BAE Systems

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

THIS SERIES BEGAN A YEAR AGO BY EXAMINING ALTERNATIVES TO Google Earth Enterprise, which Google will stop supporting on March 22, 2017; it then expanded to review a wide range of tools for geospatial visualization and analysis. For this installment, I discussed their companies' offerings with:

- Pat Ernst, Co-Founder and COO, PIXIA;
- Riordon Kossen, Field Marketing Manager, Luciad NV; and
- Kurt DeVenecia, Deputy Director GXP Product Development, GXP Technology Area, BAE Systems.

PIXIA: FILTERING DATA ON THE FLY

PIXIA has traditionally focused on data storage, access, and management, particularly with regard to very large geospatial data—including aerial and satellite imagery, full motion video, Wide Area Motion Imagery (WAMI), lidar, and SAR. While some may not find storing and retrieving data particularly exciting, Ernst says, "We feel that it is a very important foundation to enable the entire value chain, including analytics and knowledge generation."

While some of its customers prefer to run their software on their own infrastructure, PIXIA can provide a data hosting and management service or run it in something like Amazon Web Services (AWS). Its Kiosk product, part of its HiPER LOOK family of products, can also generate deployable drives that serve disconnected users. "It allows users to take a lot of data that is under management and tailor it to these disconnected drive servers," says Ernst. They can be on commodity external hard drives, all the way down to microSD cards, and access the data through a local Web services call that does not require Internet connectivity.

Whenever possible, PIXIA's products leverage OGC services—such as WMS, WMTS, and WCS—to download data. "Whether you are using a thin client—we have one called HiPER EARTH—or Cesium or some derivative thereof, or ArcGIS Earth, Google Earth, OpenLayers, or Luciad, you can access the data directly through these OGC services," says Ernst. "That includes other types of thick clients, such as Arc and SOCET."

PIXIA enables users to filter processed point-cloud lidar data on the fly and generate hill-shaded relief and other views, because on the back end it does not store that data as a tile cache. "So, if they want to see, say, a bare earth representation of that or a hill-shaded relief, they can do a lot of that, remotely, on the fly," says Ernst. A more advanced user, he explains, can use GetFeatureInfo to download the LAS file and then visualize it in a more robust analytic tool, such as Quick Terrain Modeler or Quick Terrain Reader, which allows users to also spin, measure, and analyze a 3D point cloud.

"Lidar is very, very powerful, but it is really only geared toward the power user today for the most part," says Ernst. "We are making those digital elevation models available to a much broader user base that can extract information from it, start to do some more advanced filtering, look at different derivative products on the fly, and then also enable the power users to download the point-cloud lidar data."

Users can use a third-party globe in conjunction with PIXIA tools to visualize their data because the PIXIA client can merge raster and/or vector coverage coming in through a Web feature service with raster data that it is bringing in through a WMS server. PIXIA's HiPER Look service can feed Google Earth in a very seamless manner, says Ernst, as well as offer other visualization

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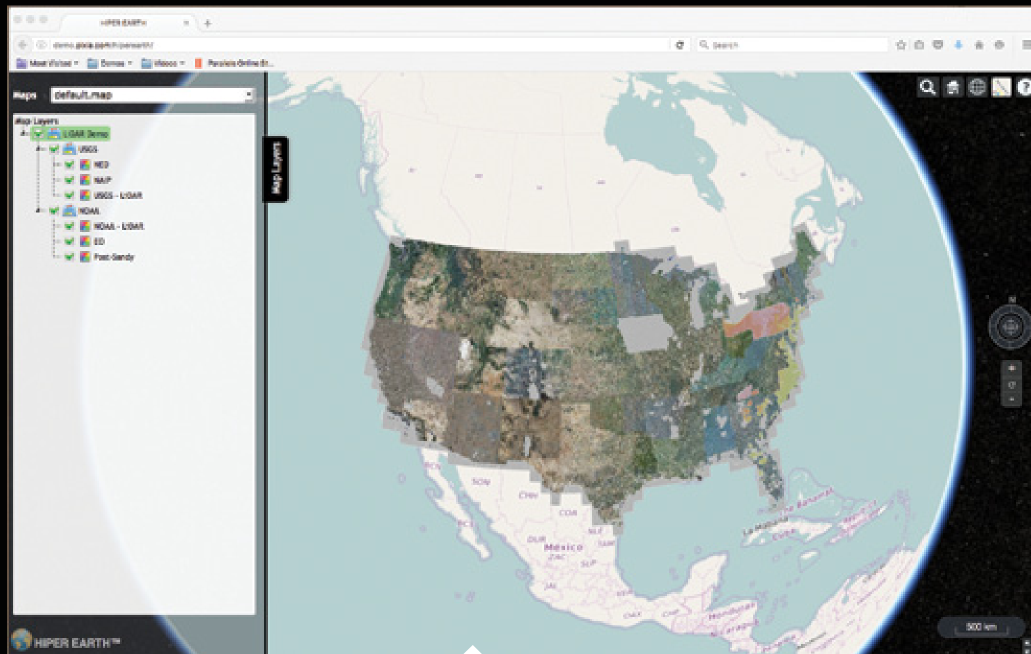

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▲ FIGURES 1-2. PIXIA's HiPER EARTH user interface provides direct visual access to the contents of the HiPER LOOK server and runs directly in an Internet browser.

and analytic capabilities, without requiring the user to make a separate copy of the data as some do now. "In our solution set, we are advocating that you make just one copy of the data and that can feed all of the different clients out there, whether thin or thick."

"At our core, we are, and always have been, extremely focused on performance and scalability," says Ernst. "So, particularly as the collection capabilities continue to advance and you are getting more high-resolution and larger volumes of data—that is really where we begin to shine, where the performance is not going to degrade." Some of PIXIA's customers manage literally tens of petabytes of data, he says, and the company wants to ensure that they are not waiting, looking at hourglasses. "Then, we focus on that dynamic aspect, so that you are not creating tile caches that are harder and more cumbersome to update, but giving the users the ability to do some of this filtering and visualization on the fly, while also keeping up a living and breathing representation of the data, as opposed to a pre-cooked version that grows stale after some period of time."

Traditionally, PIXIA's core market has been defense and intelligence. However, as commercial applications of geospatial data have continued to mature and are now using very large data volumes—particularly in such classic big data markets as oil & gas, medical imaging, and digital media entertainment—PIXIA is branching out into some of those spaces, Ernst says. It is partnering with other companies to develop collection and analytics capabilities. "As we are seeing more aerial and overhead imagery, lidar, and some of these other large datasets explode, we are also seeing some of the barriers to entry for some of these other markets start to decrease in size, so that we can start to offer managed services and to reach out to many of these organizations in a more coordinated fashion, rather than having to attack each market segment one at a time."

PIXIA has done some work in the defense and intelligence world in support of WAMI, which provides consistent surveillance of very large areas, and is now following closely its translation to commercial applications, such as to monitor production plants or oil & gas facilities. "We are very interested in looking at this idea of WAMI as a service, and partnering with some folks on the collections side of the analytics as well," says Ernst.

PIXIA's HiPER LOOK product line deals primarily with the types of data that Google Earth has dealt with. It can ingest and manage very large volumes of data and serve it out. The product line includes a thin client called HiPER EARTH. See ***Figures 1-2***.

"We have a very large variety of users out there and we feel pretty passionately that they ought to be able to bring their own clients," says Ernst. "Many times they have a strong predisposition toward a particular analytic client—such as a Cesium-based client, ArcEarth, Google Earth, OpenLayers, Luciad, FalconView, or

SOCET. We have the ability to service all of those different clients and, again, to do so through OGC services." Additionally, like Google Earth Enterprise, PIXIA can create portable globes on what it calls deployable drives. They can range anywhere from hundreds of terabytes all the way down to several hundred megabytes onto a microSD card.

"PIXIA is dedicated to developing the world's fastest and most scalable geospatial data management solutions," says Ernst.

LUCIAD: API TO BUILD ANY GEOSPATIAL APPLICATION

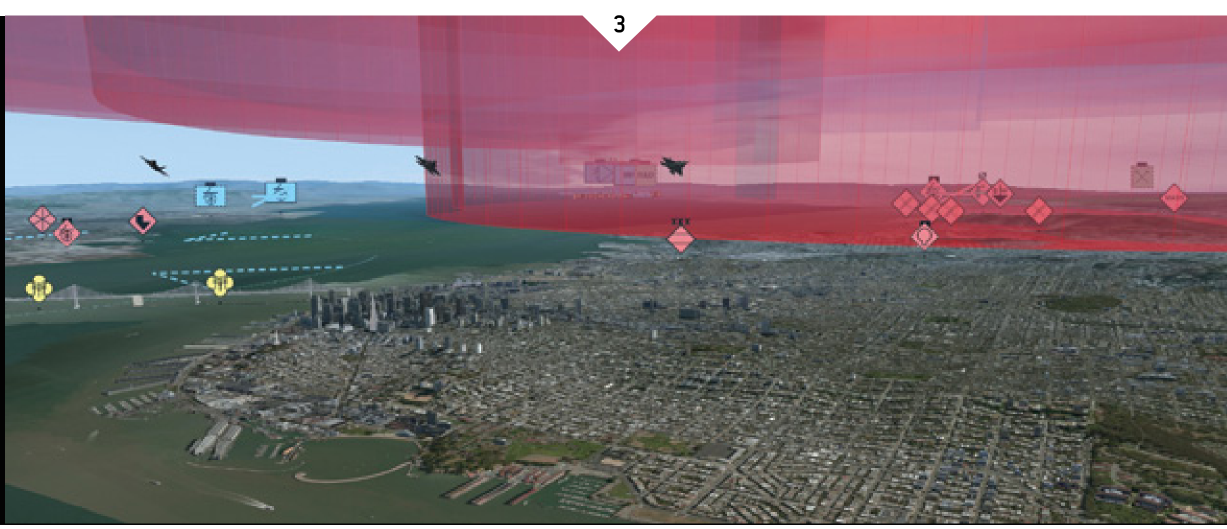
Luciad is based in Leuven, Belgium, close to Brussels, has offices around the world, and has a network of local Luciad Certified Partners. The company was founded in 1999 as a spinoff from the University of Leuven and still has a very strong link with it. The founder, Kossen recalls, was working at NATO and saw a need for geospatial visualization and merging different sources of geospatial information in a common operational picture. Such a solution was not available, so he began to develop an API that would allow developers to build any geospatial application. "That is still exactly the strength of the product today," says Kossen. "That objective has not changed over the years. Today, we still provide geospatial components to develop geospatial applications of any type that need to visualize different sets of information and draw conclusions from that, helping the user make decisions."

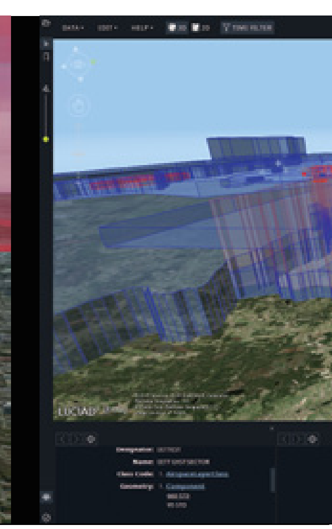
Luciad comes from a defense background. "That," says Kossen, "has helped us to become so successful, because the requirements for defense-related projects are typically very high and they are a challenge to meet." Meeting those challenges opened the doors to other domains, such as aviation, maritime, and logistics. "Moving dots on a map can be jet fighters, moving very fast, or cars on the road, moving not so fast, or a person in an amusement park that is being tracked," says Kossen. "So, our software is very well suited to handle both static and dynamic data, visualize it, and then do visual analytics that help the user make a decision." See ***Figures 3-4***.

Luciad does not sell an end-user product, but software components. It typically sells them to system integrators that develop end user systems incorporating its products. The company also has a department that supports system integrators in developing those applications and sometimes develops full applications for specific end users. Its customers range from national defense ministries to NATO to aviation authorities, such as the U.S. FAA or Eurocontrol in Europe or local entities that deal with flight information in a country, to system integrators, such as Thales, SAAB, SAIC, and Boeing.

Luciad's customers with mobile applications use LuciadMobile, those with browser-based applications use LuciadRIA, and those with server-based products run LuciadLightspeed, the company's flagship product, on desktops and servers. They may also run LuciadFusion, which is a server-side solution for managing data for distribution in large amounts or to different types of applications. "Within these products, we have a range of capabilities specific to the domains in which we are active," says Kossen. "Straight out of the box, our products support the commonly used data formats and symbologies used in the defense, aviation, and maritime sectors." See ***Figure 5***.

Connecting to the data is the first step toward visualizing it and analyzing it. "For example," says Kossen, "you can connect to a satellite image of a certain region,





▼ FIGURES 3-4. Luciad defense applications

▶ FIGURE 5. Example of LuciadRIA in a browser then combine it with elevation information, visualize street data, and visualize, for example, the airports, then show dynamic data, such as live air traffic feeds or recorded feeds. Our product contains everything needed to do that."

"Our product is developed for big data," says Kossen, both static and dynamic, as well as Twitter feeds and so on. "All of this information is very valuable if you can visualize it in a good way. We have specifically designed our products for that."

Luciad provides 2D and 3D Earth models. Together with the software components, it delivers samples and even complete starter applications. For example, Lucy is a Luciad Lightspeed application component that provides a 3D globe onto which users can drag and drop their own information. "You can export it again, you can print it, you can do everything that you can do with other basic GIS tools," says Kossen, "but you can also do advanced analysis and analytics on top of that."

LuciadFusion, a server-based application, can replace Google Enterprise Fusion, Google Enterprise Server, or Google Enterprise Portable, says Kosson. "LuciadFusion does more and better than what Google Earth is doing," he says. "So, we are positioning LuciadFusion as a replacement for it."

Luciad is also a driver of open standards, says Kossen. "We don't like closed formats so we are focusing very specifically on open standards; we support them. We are a member of the Open Geospatial Consortium."

The company also does a lot of research on big data issues, says Kossen. "Another important aspect is that we have a very unique and good tiling mechanism, which is used, for example, in LuciadFusion. It allows you to load any traditional raster and vector data and tile it and make it available to any other application, either in this tiling format or even in an open standard. It is very well optimized for combining that with other datasets, such as real-time feeds."

BAE SYSTEMS: DIGITAL PHOTOGRAMMETRY FROM STONEHENGE TO MARS

DeVenecia works for BAE Systems' Electronics Systems sector's Geospatial eXploitation Products (GXP) business group, which has about 250 employees and produces mostly software products. "Our software started out with desktop applications," he recalls. "We basically replaced the old analytical plotters with SOCET SET. That was the beginning of digital photogrammetry." Over the years, BAE Systems advanced SOCET SET into SOCET GXP, which is now its premier desktop solution for exploiting imagery and other geospatial information. "It does a lot more than SOCET SET did," says DeVenecia. "It runs the gamut from photogrammetry to very simple image analysis. So, our user base is much broader than it was with our previous software solution."

BAE Systems then moved into server software and developed the GXP Platform, which is the foundation for derived products that it has running in browser applications. "The GXP Xplorer search and discovery tool finds geospatial and non-geospatial data for you," DeVenecia explains. "It allows you to query all that information and serve it to other products, like GXP WebView, which is our imagery exploitation tool in the browser, and SOCET GXP, as a client in the desktop. We also have mobile solutions, GXP Xplorer Mobile and GXP Snap, which are also enabled by the GXP Platform. Our new product is GXP OnScene, which provides support for the first responder market." See ***Figures 6 and 8***.

While BAE Systems offers a database for storing and extracting features and vectors out of imagery, "for true

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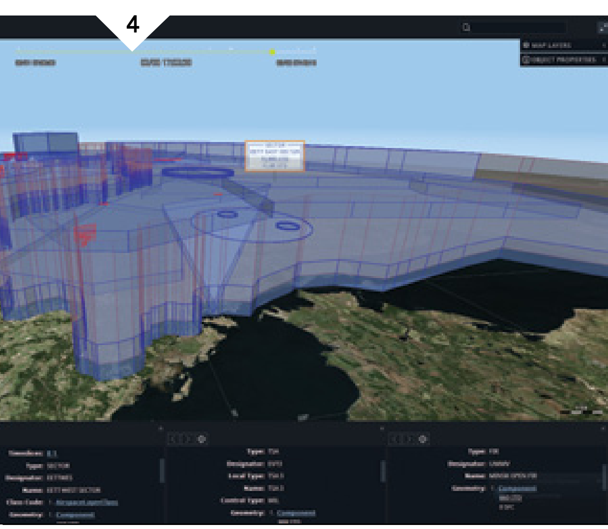

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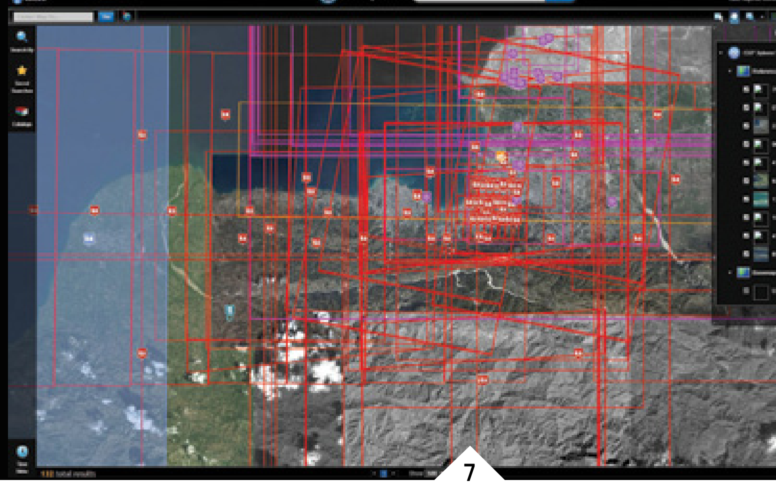

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▲ FIGURE 6. Demo image from BAE Systems' GXP WebView depicting coordinates, measurements, and additional annotation capabilities. Imagery courtesy of DigitalGlobe.

▶ FIGURE 7. Demo image from BAE Systems' GXP Xplorer depicting available data footprints and Layer Manager capability. Imagery courtesy of DigitalGlobe.

▶ FIGURE 8. A Common Response Graphic (CRG) displayed on a mobile device for first responders in the field. Imagery courtesy of EagleView Technologies, Inc. Used with permission.

GIS," says DeVenecia, "we partner with Esri. People use our applications to feed information into ArcGIS and we also use the content out of GIS in our applications."

GXP Xplorer's background is a map that can come in OGC format from Google Maps or from WMS or WMTS servers. "When people do queries and want to understand where data is for their particular area of interest," DeVenecia explains, "they see the footprints and the details and the points on a map. If there is terrain out there, the terrain footprint will show up. If there is imagery, that will show up. The same goes for video and feature data. Even documents, if they contain coordinates, will be displayed as points on the map." It crawls the enterprise for geospatial data: if data shows up at a location, the program catalogs it and then disseminates it to those who need it. See ***Figure 7***.

BAE Systems' major market is defense, but it also works with civilian government agencies, such as USGS. It is currently working on some of USGS' planetary missions. "The USGS built terrain models for asteroids, the moon, and Mars and things like that with our software," says DeVenecia. "USGS has integrated some of their sensor models into our software and can use them for those types of applications. USGS also works on volcanoes, so we are doing terrain analysis of volcanoes, as well as such things as developing tools to monitor volumetric changes of glaciers."

As part of the development of its GXP Platform software, BAE Systems has built upon its legacy developing server software containing a rich set of algorithms for exploiting imagery and performing photogrammetric math. It hosts that server solution on AWS and provides applications that allow first responders to communicate, collaborate, and share information using a Common Response Graphic (CRG), which DeVenecia likens to a Thomas Brothers grid on top of an image. "That way," he says, "they can easily communicate with one another on current, relevant imagery and track each other. Our commander application allows command and control elements to help orchestrate where people are and where they need to go. That is one of our emerging markets."

BAE Systems, according to DeVenecia, has had conversations with DigitalGlobe on putting its algorithms on the latter's GBDX platform. "We use their content in our applications, but they don't have our algorithms within GBDX yet. They are a content provider for our GXP Platform, along with a number of other satellite imagery providers and aerial photography firms."

BAE Systems is also involved in close-range photogrammetry. The USGS used BAE Systems software on its Mars missions to derive some of the close-range models of the rocks and craters it was investigating in front of the rover. BAE Systems software was also used to model Stonehenge from close-range images. "The application works quite well in close range as well as in normal photogrammetry applications, such as with satellites and aerial photography," says DeVenecia.

BAE Systems' applications "are very tuned to doing things in a rigorous sense," says DeVenecia. "We have been doing digital photogrammetry for decades. We were probably the first ones to actually do digital photogrammetry for the U.S. government. So, our algorithms are sound and they are the foundation for the work that we do."

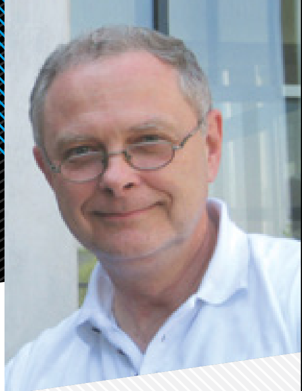
Probably BAE Systems' key discriminator, DeVenecia says, is being able to derive information from oblique images that have not been altered and orthorectified, while also being able to serve out imagery as OGC-specific content for end users.

"Our customers use Google Earth Enterprise, Google Earth, and Google Maps with our software for things like collaboration and situational awareness," says DeVenecia. "They are able to take our derived products or the products that they derive from our solutions and put them on top of the Google Earth globe in KML format. However, that is something that our users

are moving away from because it is going away." GXP Xplorer can be used to collaborate and share information at an enterprise level.

"The amount of geospatial information in our hands is just tremendous," says DeVenecia, pointing to both traditional sources and new ones such as UAS and mini-satellites. Therefore, he argues, automation is a key to analyzing all of this vast quantity of geospatial content and deriving answers from it. One bottleneck, he points out, are some of the communications networks, which can make it challenging to use the servers to their maximum efficiency and get the answers across the networks and out to the end users.

Users require and expect more sophisticated tools to visualize and analyze remotely sensed geospatial data—whether they be static features, slow-moving pedestrians, or fast-moving vehicles, and whether the imagery be nadir or oblique, orthorectified or not. As advances in collection capabilities continuously increase the already tremendous volume and resolution of this data, the companies profiled in this series continue to develop new ways to merge and visualize them in a common operational picture. ∧σ



Report on 2016 UNCOPUOS Meeting

EARTH OBSERVATIONS HIGHLIGHTS

Michael K. Simpson, PhD
Executive Director
Secure World Foundation
Broomfield, Colo.
www.swfound.org

FOR PEOPLE WHO CARE ABOUT SPACE-BASED EARTH observation, this is a good time to pay attention to the United Nations' space agenda.

Although one can hear a lot of skepticism about the pace and efficacy of the UN's approach to space policy, the General Assembly and its committees remain the most broadly international forum of discussion for political issues affecting space applications. They also provide good insight into the perspectives of over 130 of its member countries that are not yet operating satellites but who are a growing part of the customer base for Earth observation services.

In recent months the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) took up one agenda item directly focused on Earth observation from space and several others that also affect the sector in important ways. UNCOPUOS reports to the General Assembly and its annual report is usually adopted with few modifications as a resolution of the United Nations. Although such resolutions are not legally binding, they often impact the development of national legislation or regulation in UN member states.

At this year's session of UNCOPUOS, the Committee deliberated on the report of its Scientific and Technical Subcommittee (STSC) including an agenda item entitled, "Matters relating to remote sensing of the Earth by satellite, including applications for developing countries and monitoring of the Earth's environment." From the item title alone it is clear that economic development and climate change are both high priorities within the UN system. Much attention is therefore focused on how Earth observation can advance objectives in both areas.

Providers of Earth observation imagery who are engaged in capacity-building projects in developing countries or in data-sharing programs will find a lot of support for their work in the UNCOPUOS report, as will those whose products are improving the quality of environmental monitoring.

Agenda items first taken up by STSC on space debris, space-system-based disaster management support, the use and application of the Group on Earth Observations (GEO), and the long-term sustainability of space activities all received considerable attention from the full committee.

In the case of the Long Term Sustainability of Space Activities (LTSSA), UNCOPUOS recommended the adoption of 12 guidelines while referring several others to next year's committee sessions for further deliberation. Predictably, as the first ever to achieve consensus within the Committee, the recommended guidelines are extraordinarily general while those still under discussion are more specific. If next year's session can increase the number and specificity of the guidelines, they may well become an important consideration in business and distribution planning for both public and private sources of Earth observation data.

Even as they currently stand, the guidelines reveal a deepening concern among UN member states about the challenges of space debris, space traffic management, space weather, and the increasing competition for radio frequency spectrum. Encouragingly, the guidelines also emphasize the need for countries newly active in space operations to ensure that their activities receive adequate national oversight to ensure compliance with international obligations.

UNCOPUOS also has a Legal Subcommittee (LSC) whose deliberations feed into the full committee's program of work. This year in addition to sharing STSC's interest in space debris and space traffic management, LSC held discussions directly relevant to Earth observation on matters relating to the definition and delimitation of outer space and to the application of international law to small satellite activities.

For those looking into activities using high-altitude platform systems or what Dr. Joseph Pelton refers to as "protospace," any discussion, particularly international, that seeks to define where space begins could have a profound effect on which law, space law or air law, applies. Although no consensus definition seems to be on the horizon, it is best to know where critical issues are being discussed.

The quest to delimit space has occupied the UN agenda for decades, but the small satellite question is much more recent. In this latter case, debate within LSC and the Full Committee reveals a strong divergence of opinion among many established space powers who see small satellites as a possible source of unmanageable debris, and the new space actors. This latter group sees smallsats as a long-sought opportunity to gain independent access to space assets focused on the needs of developing countries and/or newly conceived business models. With many new EO applications being proposed based on smallsat architectures, this part of the UN agenda, too, is one not to be ignored. In fact, there might be business opportunities for those who can reconcile the growing desire for access with the need to avoid making the orbital debris problem worse.

2017 INITIATIVES

Looking ahead, next year's meetings of UNCOPUOS and its subcommittees propose to continue discussion of the items taken up this year while adding two important new initiatives. In 2017, LSC will take up the issue of space mining for the first time under an agenda item entitled, "General exchange of views on potential legal models for activities in exploration, exploitation and utilization of space resources." Since most of the technologies necessary to characterize celestial bodies with sites worthy of commercial development will be drawn from the EO toolkit, these discussions will bear watching. Where warranted, expert input into them can be provided through national delegations of any of the 84 members of UNCOPUOS.

Sometimes even proposals receiving little or only limited support can be interesting to note. This year Egypt and Syria proposed an aggressive program of EO data sharing to combat terrorism. Many delegations appeared skeptical about the end use of such shared data and so the proposal was not forwarded to the General Assembly with the Committee's consensus recommendations.

UNISPACE+50

Perhaps of greatest importance, the 2016 UNCOPUOS meetings endorsed thematic priorities for the preparation of what will be only the fourth UN Conference on space policy in the organization's history. This conference is scheduled to take place in 2018 on the 50th Anniversary of the first UNISPACE Conference. Given that the Vienna Declaration that emerged from the last one, UNISPACE III held in 1999, has been the primary driver of the United Nations space policy agenda ever since, the upcoming conference, to be called UNISPACE+50, is likely to impact space policy making for at least a decade into the future. The thematic priorities clearly resonate with the interests of most members of the EO community:

1. Global partnership in space exploration and innovation
2. Legal regime of outer space and global space governance: current and future perspectives
3. Enhanced information exchange on space objects and events (SSA data sharing for the most part)
4. International framework for space weather services
5. Strengthened space cooperation for global health
6. International cooperation towards low-emission and resilient societies
7. Capacity-building for the twenty-first century

While international deliberations on matters of interest to the Earth observation community are unlikely to impact operations, capabilities, and priorities as directly as will national legislation and regulation, they are also likely to have a growing impact on activity that is global by its nature and that is high profile for governments who recognize their economic and political importance. We will continue to update you on the discussions as they continue and deepen.

UNCOPUOS has been a leader in transparency, posting its documents and reports online and making audio copies of its debates available to the public. This year's UNCOPUOS report is available at: http://www.unoosa.org/res/oosadoc/data/documents/2015/a/a7120_0_html/A_71_20EAEV.pdf

Digital recordings of this year's committee proceedings can be found at: http://www.unoosa.org/oosa/audio/v2/meetings.jsp?lng=en

Supporting Agenda 2030's Sustainable Development

Agent-Based Models and GeoDesign

SHELLEY-ANN JULES-PLAG / PRESIDENT / TIWAH UG / WWW.TIWAH.COM / GERMANY

AND HANS-PETER PLAG / DIRECTOR / MITIGATION AND ADAPTATION RESEARCH INSTITUTE
OLD DOMINION UNIVERSITY / WWW.MARI-ODU.ORG / NORFOLK, VA.

In October 2015, the United Nations' Plenary agreed on Agenda 2030, the "Road to Dignity," as the Secretary General of the United Nations denotes it, which aims to achieve seventeen ambitious Sustainable Development Goals (SDGs) by 2030. The SDGs cover almost all areas of human activities and their impact on Earth's life-support system (Table 1).

THE COMPLEX SYSTEM CHALLENGE

Each of the broad goals has a set of associated tangible targets. Each target comes with a set of target-specific indicators to measure the progress towards the targets. Making progress towards these targets will require the development of policies and the implementation of specific actions that can facilitate this progress.

It is a foregone conclusion that due to the broad nature of the goals and the global intergovernmental involvement, achieving each individual goal presents a complex system challenge. All goals pose highly complex problems to society. For many of the goals it is not evident that they are achievable, or achievable by 2030. For example, SDG 1 aims at "Ending poverty in all its forms everywhere." However, the absolute number of people living in extreme poverty has not changed very much since 1800, when an estimated 95% of the global population of close to one billion was living in extreme poverty, although the fraction has gone down very much due to a rapid growth in population since then. Some goals may not be understood in the same way in different countries and cultural settings. For example, SDG 5 has the aim to "Achieve gender equality and empower all women and girls," and it is not clear that this goal is understood across all cultural and religious settings in the same way.

Author's Note:
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An important question to ask is whether the targets as they are defined will actually bring us closer to the goals. This question can only be answered by fully acknowledging the complex challenge each of the goals presents to society. There are research needs to better understand the systemic conditions that are required in order to make progress toward the targets[1] and to assess to what extent reaching the targets also implies reaching the goals.

Another challenge is the interconnected nature of the goals and targets, which requires straddling the interests of different policymaking departments at national levels. For example, how can conflicting

Goals

requirements for achieving "No Poverty" (Goal 1) and "Zero Hunger" (Goal 2) on the one side and "Life Below Water" (Goal 14) and "Life on Land" (Goal 15) on the other side be resolved? Additionally, the interconnected nature of the goals and targets poses a cross-country challenge considering the different interests and priorities of policymakers in different countries due to inherent differences in cultures and the perception of risk. The priority given to sustainability over other goals also differs from country to country and policymaker to policymaker.

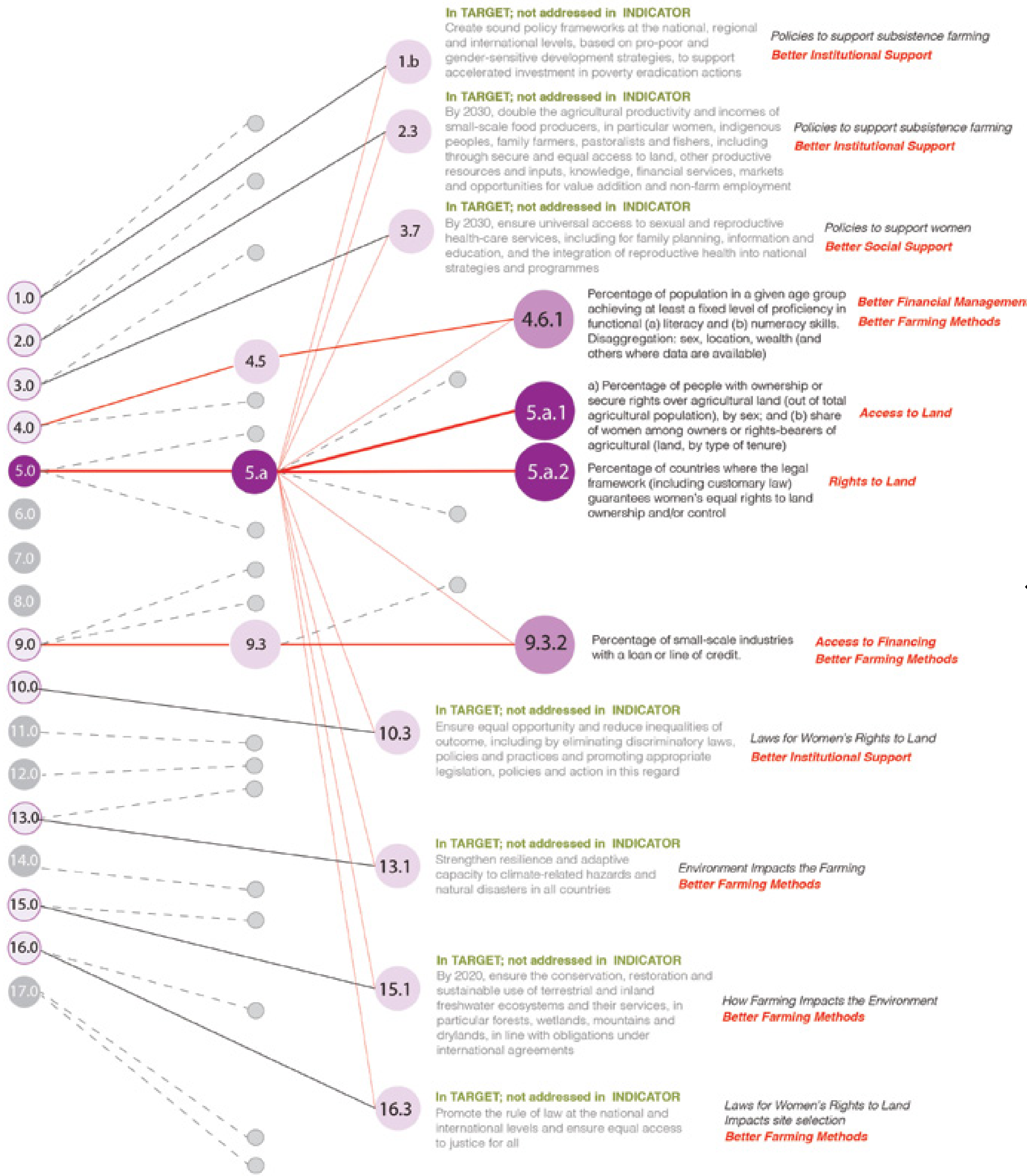
Together, this mesh of issues presents a challenge to achieving the overarching objective of putting the world on a sustainable course. It is clear, however, that making progress towards the SDGs requires Earth observation and science support to address the questions that need to be raised for each goal:

1. To what extent are the goals achievable?
2. Are the goals well-defined and understood in different countries in comparable ways?
3. How can the complexity of the goals and associated targets be accounted for in policymaking?
4. Are the targets sufficiently focused on achieving the goals?
5. What policies and actions can facilitate progress towards the targets?
6. Are the indicators well-defined and providing a measure of progress towards the targets and goals?

TABLE 1: The Agenda 2030 Sustainable Development Goals

GOALS	DESCRIPTION OF GOALS
1. No Poverty	End poverty in all forms everywhere
2. Zero Hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3. Good Health and Well-being	Ensure healthy lives and promote well-being for all at all ages
4. Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5. Gender Equality	Achieve gender equality and empowerment for all women and girls
6. Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all
7. Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy for all
8. Decent Work and Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9. Industry, Innovation and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10. Reduced Inequalities	Reduce inequality within and among countries
11. Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient and sustainable
12. Responsible Consumption and Production	Ensure sustainable consumption and production patterns
13. Climate Action	Take urgent action to combat climate change and its impacts
14. Life Below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15. Life on Land	Sustainably manage forests, combat desertification, and halt and reverse land degradation, halt biodiversity loss
16. Peace, Justice and Strong Institutions	Promote just, peaceful and inclusive societies
17. Partnership for Goals	Revitalize the global partnership for sustainable development

FIGURE 1: Relevance of Different Goals & Targets to Meeting Goal 5 for Gender Equality, in Subsistence Farming



Open data, as strongly promoted by the Group on Earth Observations (GEO), is mandatory for the monitoring of progress towards the SDG targets,[2] and a refocusing of Earth observations and science support on the needs of the Agenda 2030 is central for making progress in the global effort for sustainable development.[3] The GEO Initiative 18 "Earth Observations in Service of the 2030 Agenda for Sustainable Development" facilitates Earth observation-based support for the Agenda 2030. However, answering the questions requires more science-based tools. Here, we look at the capability of two approaches to addressing some of these questions. We look at the benefits and limitations of an Agent-Based Model (ABM) approach and a GeoDesign approach.

AGENT-BASED MODELS APPLIED TO GENDER INEQUALITY

Equation-based models have very limited value for problems as complex as reaching the targets and SDGs.[4] The advantage of ABMs is in the ability to provide an environment for us to experiment and explore when we are not totally clear on all of the issues impacting a problem. Predictions can come later when we are better informed and the explicit nature of the ABM has provided tested evidence of certain results. During the programming phase of ABM development, we need to formulate a clearly defined problem because computers are not equipped to handle the ambiguity of an ill-defined concept.

This is where the power of the ABM manifestation is twofold. First, due to the need for formalized rules, we can look at and have a better understanding of the impact of the assumptions that are made in our interpretation of the complex system (i.e., system composition such as boundaries, time-frame, scale, etc.). It allows us to look at various scenarios, test assumptions, assess internal model consistencies, and address sensitivities such as relation to data. Experimentation with the ABM helps us to identify the most relevant aspects and the core issues impacting our goals.

ABMs provide avenues for the incorporation of domain expertise in a rigorous manner. With this, the ABM development also guides data collection and illuminates the core dynamics.[4] The iterative process of ABM development facilitates a more defined and eventually more refined model, ultimately giving us better direction with respect to where efforts should be placed to arrive at the desired goal.

The second benefit of the formalization of rules is that the model can be generalized and applied over different domains, providing the value of repeatability.

To illustrate the versatility of ABMs, we look at Goal 5 (Gender Equality, see ***Table 1***). The forms of gender inequality differ across cultural regions, and the spectrum of economic and social barriers for progress towards the goal has considerable spatial variability. It would be impossible to take a comprehensive look at the scope of this goal, so here one branch of policy support is considered.

On a global scale, economic gender inequality is evident in the fact that 70% of all work is carried out by women but they only earn 10% of the global income. A specific example is subsistence farming: In societies with a large fraction of subsistence farming, the majority of the subsistence farming work is carried out by women. One of the major hurdles to gender equality in these societies is a woman's inability to own land and gain access to financing. Most of the land is owned by men or by tribal organizations dominated by men. Most financing goes to men, thus solidifying and continuing the cycle of gender inequality. This aspect of gender inequality is broadly addressed by Target 5.a.:

5.a: Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws.

This target is open to interpretation and reinterpretation by all countries and policymakers. The indicators for Target 5.a are more specific, adhering to a metric. They however are decoupled from other relevant factors:

5.a.1: (a) Percentage of people with ownership or secure rights over agricultural land (out of total agricultural population), by sex; and (b) share of women among owners or rights-bearers of agricultural land, by type of tenure.

5.a.2: Percentage of countries where the legal framework (including customary law) guarantees women's equal rights to land ownership and/or control.

In order to explore the variables associated with these indicators, the factors that directly and indirectly impact a woman's ability to conduct subsistence farming have to be considered. The complexity involved in determining these impacts is presented in ***Figure 1***. Based on the issues and the broad nature of the goals and targets, it is necessary to combine the goal-based "top down" approach with a practical "bottom up" approach. The "top down" approach facilitates a transportable decision support for all the SDGs, while the "bottom up" approach considers the individual factors and their specific impact on the indicator for a specific target and goal.

As an initial step, we have developed an ABM

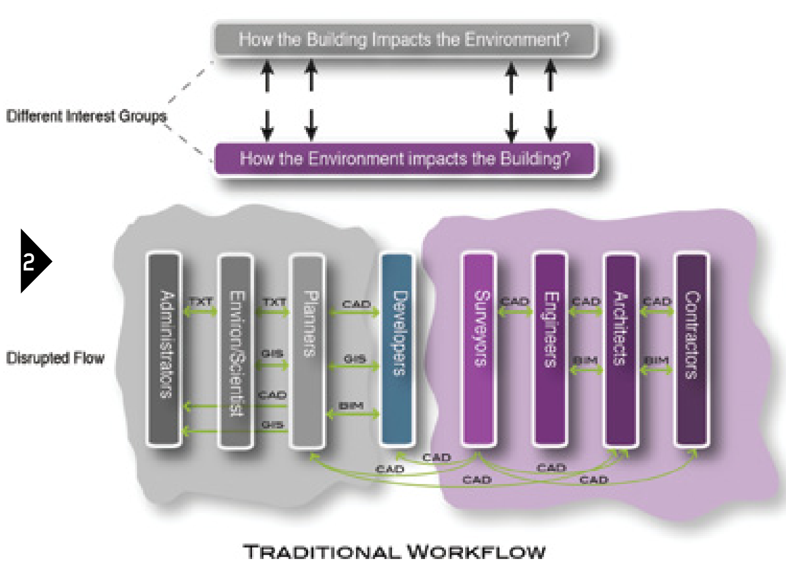
▼ FIGURE 2: The traditional workflow in designing the built environment

▶ FIGURE 3. A GeoDesign Hub provides an interdisciplinary collaborative platform for the development of options

for subsistence farming. The aim of the ABM experiment is to determine the factors that impact gender equality through land ownership and access to financing in support of subsistence farming by addressing the questions:

- How does distribution of land title impact the success of female farmers?
- How does access to financing impact the success of female farmers?
- How does discrimination at market impact the success of female farmers?
- How does climate change impact the success of female farmers?
- Based on the results, what are the apparent gaps that exist between the SDG indicators and the factors the analysis identify as impactful?
- Based on the results, what are the policies that can be put into place to help support the success of female farmers?

Policy options in the ABM to increase equality are those that impact land ownership and access to financing. The initial exploratory system model simulates the seasonal cycle of buying seeds (including getting financing, if needed), seeding, growing, harvesting, and utilizing (marginal) gains. The agents are the male and female farmers, land-owner societies, markets to buy seeds and fertilizers and sell produce, traditional financial sources (banks) and micro-financing actors. This model was run over the seasonal cycle for a period of 100 years for many different scenarios.



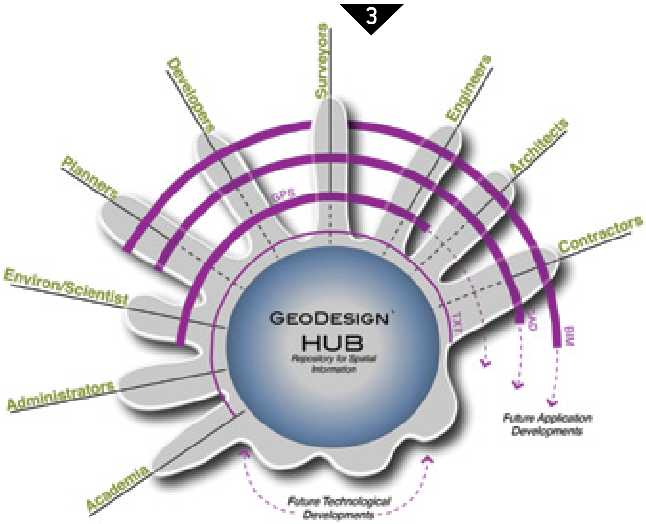
The information obtained from the analysis provides valuable guidance to the policy conditions that have the potential to improve the success of subsistence farming by female farmers and reduce gender inequality. Decoupling land ownership from financing and introducing quota systems are two potential policy options that may be considered based on the results. Additionally, the results help to identify where there are gaps in the current formulation of targets and indicators towards more goal-focused policy development.

These considerations informed by the ABM experiment provide guidance for further developing the ABM. Of course, access to land and finance are only the start of the subsistence farming process. In order for a woman to maintain land rights she must be successful in the subsistence farming project. As outlined in this simplified view of the interrelationship of the SDGs, better farming methods, institutional support for land ownership and financial support have contributions made through SGDs 1, 2, 3, 4, 9, 10, 13, 15 and to a lesser degree 16. Of course, additional connections with the other goals can be determined with further analysis. Here we focus on the indicators 5.a.1 and 5.a.2 and the relevance of 4.6.1 and 9.3.2. It should be noted that the ABM in its current form does not reflect the full complexity of Target 5.a, but it provides an exploratory and explanatory approach to modeling aspect of Goal 5.

GEODESIGN APPLIED TO SUSTAINABLE CITIES

GeoDesign operates in the realm of infrastructure and the built environment. It facilitates informed development in advance of perceived needs, thus leading to sustainable construction development. The interoperability of technology facilitates integration of the subsystems of research and construction from the macro to the micro level, essentially developing conflict resolution mechanisms. It has the potential to bridge the gaps among science, social needs, economics, and policy, helping to resolve issues involved in designing the built environment. Integrating technologies offers a dynamic way of representing unseen patterns and contextual relationships across global, regional and local areas.

Figure 2 illustrates the traditional workflow process with disciplines contained in silos. Movement from the administrative stage to the building stage



is disjointed and involves a hand-off. This often inhibits the flow of information essential for responsive design. ***Figure 2*** also illustrates the conflicting interests that are inherent in traditional planning of human settlement. Each of the major players serves a different core interest and they speak a different discipline-specific language.

The development of a GeoDesign Hub (***Figure 3***) made possible by interoperability facilitates the smooth flow of captured data to the disciplines and areas where it is needed in a timely manner. Information created through "data informed processes" re-enters the Hub making the system more intelligent. Feedback from the various disciplines and crowdsourcing further informs the development of educational needs. Thus the interoperability of technology brings sustainability and its facets, such as disaster risk, resilience, adaptive capacity, and livelihood into the design argument.

When interoperability is optimized, development has the ability to go from the point of impetus to examples of potential 'built' models. Similar to the ABM outlined above, it gives us the ability to explore scenario iterations in the design process. It allows the signal that triggered the course of development to be amplified throughout the course of development.

Considering Goal 11, which aims to "Make cities and human settlements inclusive, safe, resilient, and sustainable," the GeoDesign approach can help by facilitating a better understanding of why we build and what the goals are. Even moreso, it allows us to account for the relation of cities and human settlements to all the other goals.

The targets of Goal 11 focus on access to housing, transportation and green spaces, the promotion of planning and the enhancement of architecture and technology to reduce pollution and improve resilience to climate change, thus minimizing the loss of human life and resources (paying special attention to the protection of natural heritage centers). Similar to the case of Goal 5, many of the other goals have targets that are relevant to the targets of Goal 11 (***Figure 4***), but the indicators for these targets mostly are not focused on the scope of Goal 11. A particular challenge for the targets of Goal 11 is in the development of indicators for such wide targets. We consider two of the targets relevant to the development of sustainable human settlements:

Target 11.1: By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.

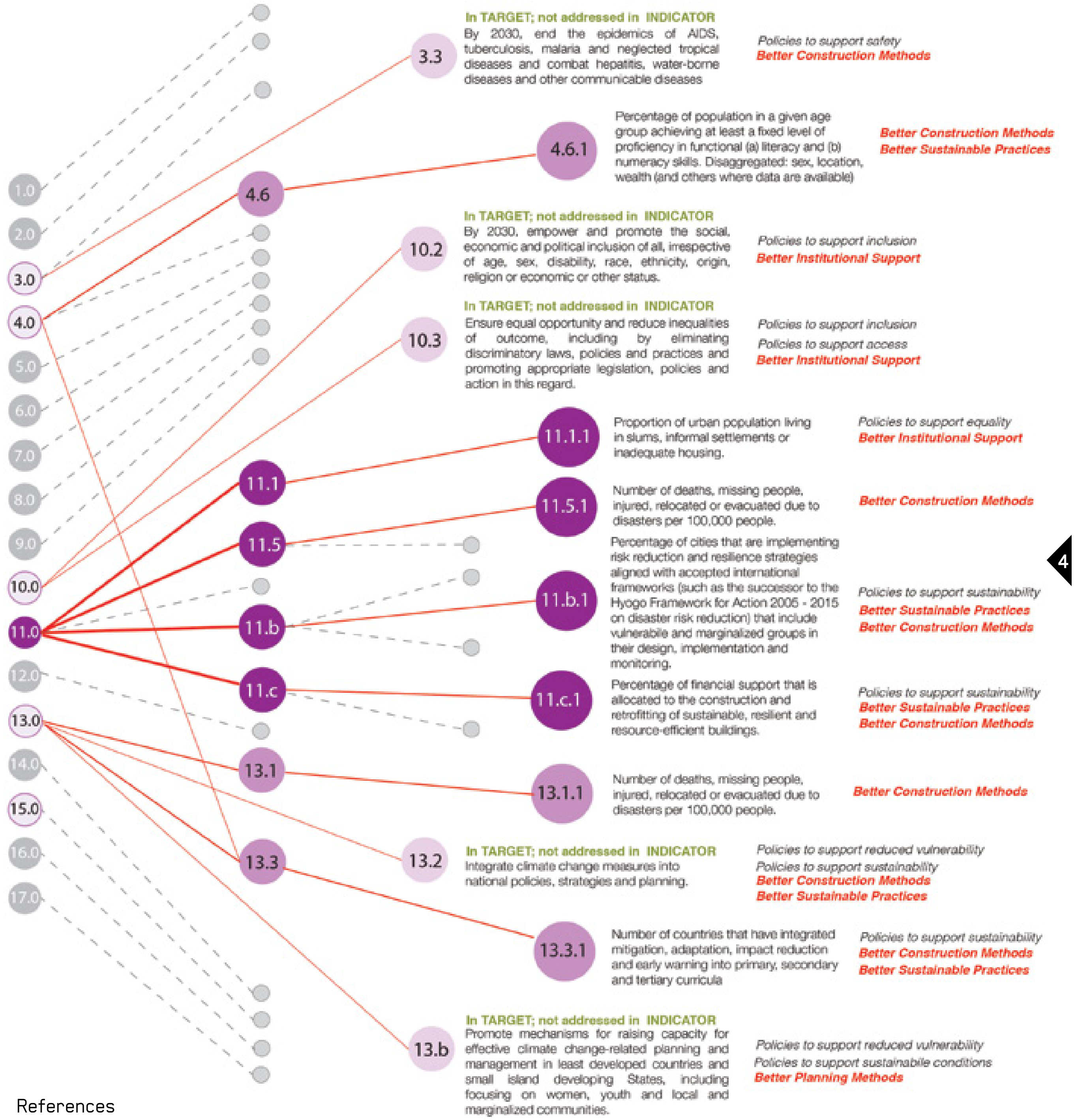
Target 11.5: By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.

The associated indicators shown in ***Figure 4*** appear to be well connected to these targets and providing a measure for progress towards the targets, but the granularity with respect to the goal is low.

OUTLOOK

For each of the goals, the questions formulated in the first section need to be answered thoroughly, and this requires a complex system approach. The ABM experiment introduced here underlines the versatility of ABMs for interdisciplinary and collaborative studies informing the development of policy that facilitates progress towards the targets. The GeoDesign Hub is an excellent candidate for a collaborative platform for those goals related to the built environment and its impact on society and environment. It will be important to link both the ABMs and GeoDesign Hubs to a comprehensive and open database integrating environmental with socio-economic data and statistics. The efforts currently underway in GEO towards open and integrated data and knowledge and the linkage to models are an

FIGURE 4: Relevance of Different Goals & Targets to Meeting Goal 11 for Sustainable Human Settlements



important development in this direction. However, it is clear that the diversity and breadth of the goals require a hybrid approach, as no one method can be a "catch-all." The examples considered here demonstrate the importance of the interaction between goals and targets and the need to capture the factors that play a role across sets of targets and goals. ∧♂

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The Rakaia River carries glacial run-off through pastureland and into the Pacific Ocean, at Canterbury, New Zealand. Image captured March 26, 2016, courtesy of Planet.

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