APOGEO SPATIAL

ELEVATING GLOBAL AWARENESS

Faster Data Downlink for Disasters: Learning from the SatCom Sector

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The Economic Impact of Space-Based Big Data

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SERIES: Geospatial Analytics-as-a-Service: Astro Digital and Descartes Labs Bring Machine Learning

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INTEGRATED UAVs + LiDAR SOLUTIONS:

Velodyne LiDAR + BoE Systems
YellowScan + Quantum Systems *p. 24*

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– Dylan Taylor, Founder, Space Angels & Space for Humanity

FORMERLY Imaging NOTES

LiDAR point cloud image courtesy of Velodyne LiDAR, Inc.

[Winter 2018 / Vol. 33 / No. 1]

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APOGEO SPATIAL

[Winter 2018 / Vol. 33 / No. 1]

Columns

Features

COVER IMAGE

Point Cloud of San Jose, California

THIS OVERHEAD IMAGE of downtown San Jose, California, was taken in the Fall of 2017 with just a single pass from a vehicle outfitted with one of Velodyne's HDL-32E 3D LiDAR sensors. LiDAR, especially those sensors that can rotate a full 360-degrees, provide a richer dataset that creates a high-resolution 3D image once it's post-processed, in this case by Kaarta (formerly Real Earth).

Currently, LiDAR solutions are capable of producing 300,000-2.2 million data points per second which range up to 200 meters with an accuracy typically to {±3} cm. This results in the generation of a very accurate and detailed 3D point cloud, which is important for customers in the 3D mapping/imaging and autonomous driving sectors.

Velodyne's LiDAR sensors allow customers like BoE Systems and YellowScan to interpret the rich data gathered from the environment via UAV-mounted LiDAR to create high-resolution 3D digital images critical for modern mapping and surveying.

The feature story about LiDAR begins on page 24.

Cover image courtesy of Velodyne LiDAR, Inc.

APOGEO SPATIAL

Formerly Imaging NOTES

[Winter 2018 / Vol. 33 / No. 1]

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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Apogeo Spatial has strategic partnerships with NovaSpace, a program of The Innovation Pavilion (www.innovationpavilion.com), and with The Alliance for Earth Observations, a program of The Institute for Global Environmental Strategies (www.strategies.org).

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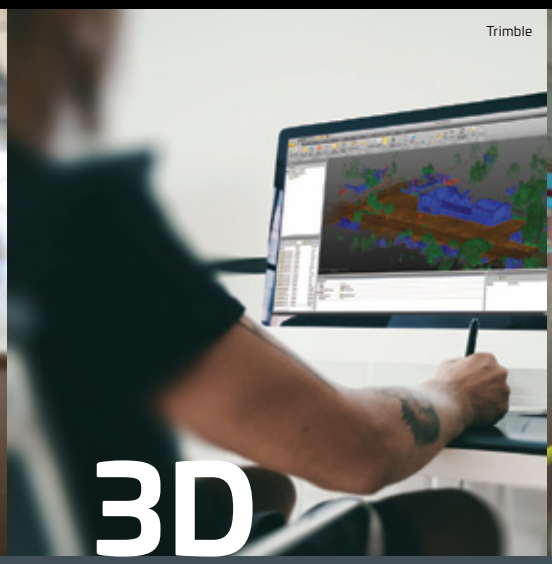
Leica Geosystems

3D SENSING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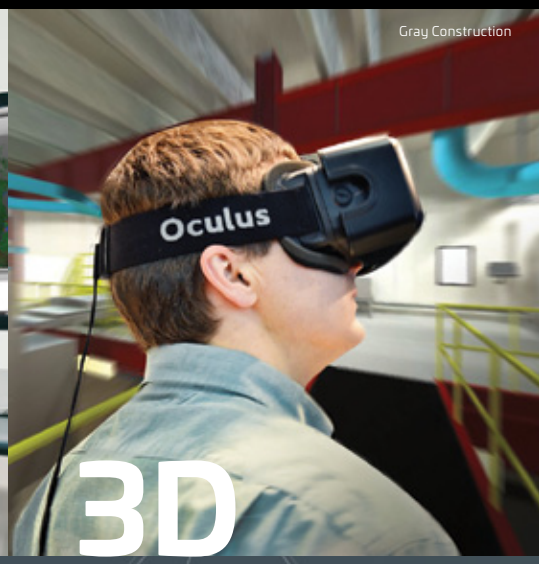
3D PROCESSING



Gray Construction

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- Allison Barto – *Ball Aerospace*
- Laura Delgado Lopez – *Harris Corporation*
- Maureen O'Brien – *Oakman Aerospace*
- Victoria Samson – *Secure World Foundation*
- Cynda Collins Arsenault – *Moderator*

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Email: katy@worlddenver.org
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For more information: https://denverworldaffairscouncil.wildapricot.org/International-Womens-Day

The Value of Space-Based Data

NOVASPACE NURTURES COLORADO SPACE STARTUPS

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DEAR READERS,

Let's start with art. A few months ago, I met Fawn Atencio, a Denver-based artist whose paintings look so much like photos of Earth that I was astounded, and inspired. Her work includes a message about a future with a lack of fresh water – an increasingly important message, as "Day Zero" (the day that water taps are predicted to run dry) looms closer for four million Cape Town, South Africa residents: April 12, 2018. Her timely gorgeous paintings, created with ink and printmaking materials, appear on page 8.

For an Executive Interview on page 10, I spoke with David Hartshorn of the Global VSAT Forum about the potential benefits of connecting the VSAT and Earth Observation communities. It is time for the different types of companies that are in the satellite business to work together and to learn from each other. Disaster preparedness and response are key areas for both sectors. Let's discuss at upcoming events, such as the SmallSat Symposium, Satellite 2018, and various disaster preparedness meetings involving the U.N., NGOs, governments and industry.

This issue brings the 2nd in our new series on Geospatial Analytics-as-a-Service, which is clearly the hottest topic in our field, as aggressive companies launch and garner more investment than other types of space companies at the moment. Data analytics is the hottest game in every town, not just ours, and we have been covering it ongoing. In this issue are featured two companies with core strength in serving the agriculture sector, Astro Digital and Descartes Labs. Featured are Bronwyn Agrios, co-founder and head of product of the former, and Fritz Schlereth, head of product of the latter.

The value of these datasets, and the upcoming "megaset," is something that Dylan Taylor has worked to quantify in his first article for *Apogeo Spatial,* "The Economic Impact of Space-Based Data." Dylan is founder of Space Angels; his views and expertise are from the standpoint of capital and company valuation. The article posits that the new space-based datasets will create the first-ever multi-trillion dollar market cap company on Earth, in the not-too-distant future!

I'm excited to announce that *Apogeo Spatial* will be working with Innovation Pavilion (www.innovationpavilion.com) to ramp up their Colorado incubator for space startups, NovaSpace, and to bring the space community together for quarterly networking and content meetings. Space and satellite companies can now be featured within the Innovation Pavilion's video segments, IPTV (www.ipnow.tv).

NovaSpace applies Innovation Pavilion's vision of productive collisions and creative solutions to the space industry by facilitating an explosion of ideas. NovaSpace will provide Colorado's space cluster, comprising 400-plus businesses and over 50,000 employees, with the community and platforms it needs to meet its growth potential by developing and strengthening connections between the space sector and the broader aerospace and defense industry.

Additional events in which we are involved include the International LiDAR Mapping Forum. Our LiDAR feature article, "Integrated UAV and LiDAR Solutions," begins on page 24 and is about systems integration for UAV and sensor manufacturers, making it much easier for end users to get the data they need.

Women in Space is the theme of International Women's Day on March 8. Dr. Mae Jemison, astronaut and first woman of color in space, will speak and I'm sure she will inspire us all. Her current mission is the 100 Year Starship (http://100yss.org/), which is working to send humans to different stars – "pursuing an extraordinary tomorrow to create a better world today."

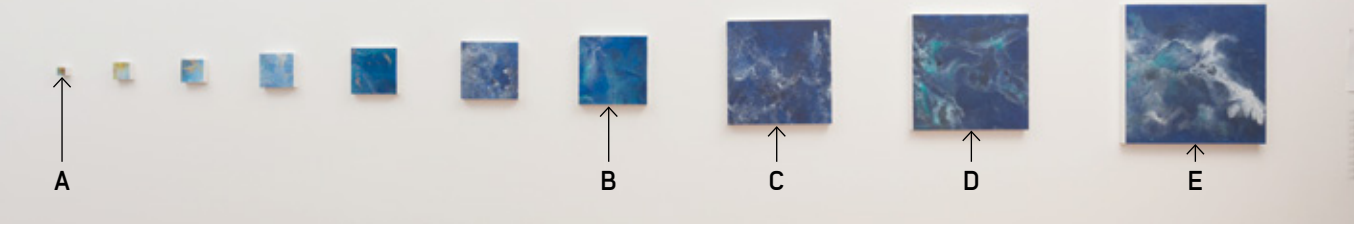
Cynda Collins Arsenault will be honored for her enduring work as founder of Secure World Foundation, an organization that is promoting cooperative solutions for space sustainability, and that has been a partner of *Apogeo Spatial* over the years.

Feeling inspired,
Myrna James Yoo

Atmospheric Terrain

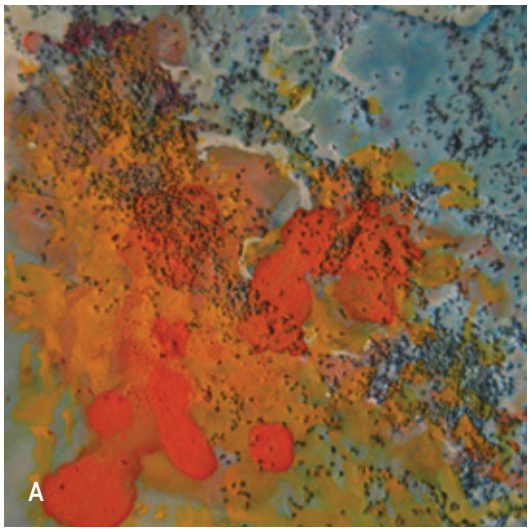
Art as Imagery: A Statement on Water

BY FAWN ATENCIO / ARTIST / DENVER, COLO.
HTTPS://WWW.MAIWYN.COM/ARTISTS-SUMMARY/FAWN-ATENCIO



ATMOSPHERIC TERRAIN PRESENTS interpretations of affected and altered bodies of water using the Colorado River upper basin as a point of departure. The paintings – representations of water – first appear clear blue, clean and abundant; they become smaller as they become drier, more orange, and polluted.

During a year-long sabbatical to North Africa and Asia, I researched and recorded how populations interface with water. I saw many geographies with limited resources of potable water. I have been exploring water's connections to the land it encroaches upon, how it behaves as it is diverted and creates new paths.



Bodies of water moderate the climate; less water means higher temperatures. Water absorbs great amounts of energy from the sun, and bodies of water release energy very slowly. For this reason, areas near water are usually more mild. Because of water's ability to absorb heat, store it and release it later, the oceans of the earth have an important role in helping to moderate the earth's temperature.

Just as the invention of photography sped up any other visual artistic process preceding it, so too does water evaporation accelerate climate change. The evaporation and diminishing bodies of water will increase temperatures worldwide, creating a series of "Butterfly Effects" that further damage the environment as we know it.

I realize there are many other ways that bodies of water affect climate, such as warm or cold temperature currents, or the Gulf Stream. However, I am focusing on the visual concept of the water cycle diminishing as an educational tool and as an image of beauty, not to tell the whole story, but to retell it as I see it.

Editor's Note:
The artist is represented by Mai Wyn Fine Art: https://www.maiwyn.com/artists-summary/fawn-atencio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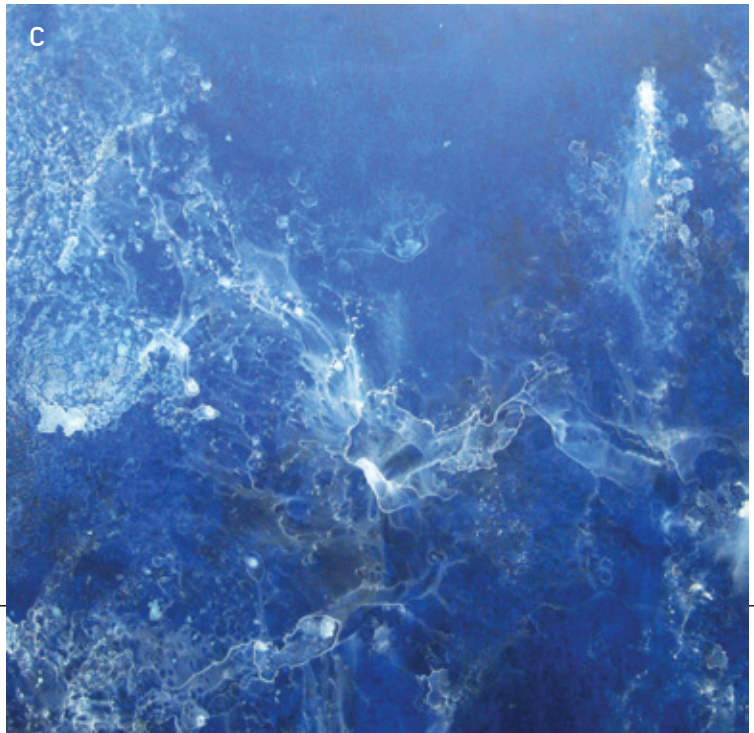
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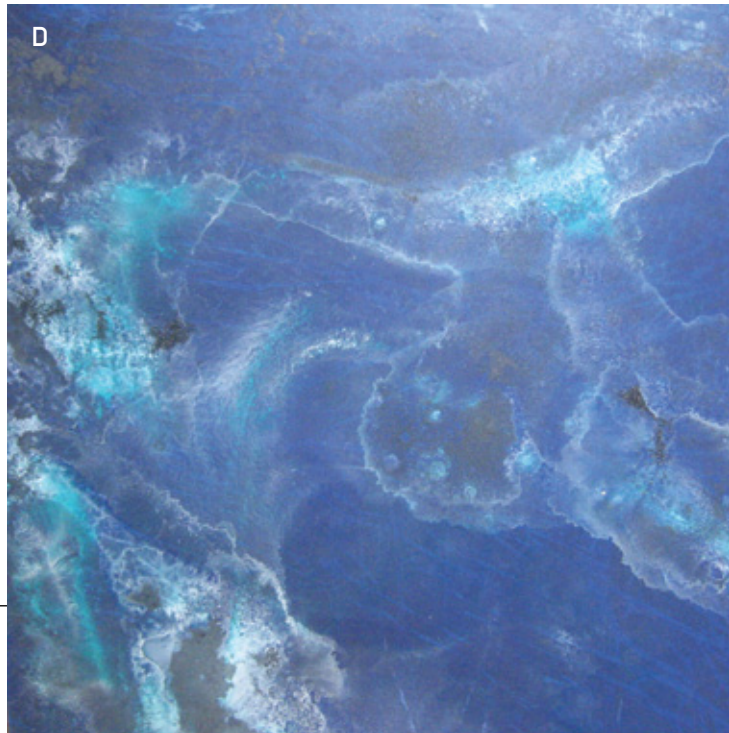
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EXECUTIVE INTERVIEW WITH DAVID HARTSHORN
SECRETARY GENERAL / GLOBAL VSAT FORUM
LONDON AND WASHINGTON D.C. / WWW.GVF.ORG

Improving Disaster Response with Faster Data Downlink

Leveraging SatCom and EO Synergies for Situational Awareness

FOR A FEW DECADES, the Earth Observations (EO) and Satellite Communications (SatCom) sectors have operated almost completely independently, with separate meetings and conferences, while many of their issues are similar. Both deal with launching and maintaining satellites in orbit, and getting data to the ground to be useful. New technologies in data downlink in SatCom could be utilized by the EO community, with particular benefits for disaster response, ultimately saving lives around the world. Myrna James Yoo, Publisher of *Apogeo Spatial*, spoke with David Hartshorn, Secretary General of Global VSAT Forum (GVF), about these issues.

JAMES YOO *David, you have been leading GVF since its inception a few decades ago. Can you share some background information?*

HARTSHORN Satellite communication is typically, at its most fundamental, a bent pipe through which information flows that would be useful in guiding and directing the efforts of the first responders on the ground during a disaster. EO obviously are a primary source of the type of data that can guide those first responders. There are other sources, of course. Crowdsourced mapping is a relatively new source of data that has begun to flow to the first responders.

However, EO information of every kind is great in providing higher levels of situational awareness, so that precious resources can be directed toward those areas most in need. Eliminating redundancy of effort is key here and Earth observation has a major role to play in that.

EO is already being used for emergency response but we want to see that data getting more deeply down range to those on the bleeding edge of the response effort. A recent development that enables that to occur at a level that has not previously been possible is the implementation, right now, in every major region of the world, of high-throughput satellite (HTS) systems and services.

The first of the high-throughput satellites were launched in 2011 in the United States by a company called ViaSat. When the first ViaSat high-throughput satellite was launched, it had a throughput on one satellite equivalent to that of every other conventional satellite over North America combined (140 Gigabit per second). So, we are talking about a capability that is orders of magnitude higher in moving data through to the recipient.

There is an important opportunity to use this capability to transmit Earth observation data before, during and after disasters.

JAMES YOO *What exactly is the technology? Is it via the Radio Frequency (RF) Spectrum, as has been used historically, or is it moving to laser communications?*

HARTSHORN At present, most HTS services are provided at RF Ka-band. This enables higher power delivered via spot beams, which allows for more efficient use of the frequency. Lasers have been proven as an effective means of delivering satellite-based communications for certain applications, but the massive extent to which Ka-band capacity has been deployed – and that will be expanded with additional short-term deployments – means that these solutions are the primary source of HTS today.

JAMES YOO *How is the development of HTS changing the economics of satellite communications?*

HARTSHORN Satellites are now a consumer play and the economies of scale

enable much lower cost equipment with that much higher throughput capability. Today, several years on, there is more than one high-throughput satellite provider in the United States and they have signed up close to two million paying consumer- and enterprise-class subscribers using that service. It is a mature service that has now proven itself. In the meantime, also, the same type of service has been rolled out in Africa, the Middle East, Asia-Pacific, Europe, South America, and elsewhere.

So, again, those economies of scale continue to mount. The GVF has begun to embed in disaster relief efforts our personnel and to work directly with the first responders to place these types of systems for support of on-the-ground operations. They love it! It works. It is much more cost-effective, it has high throughput, so we can move types of data that are very bandwidth-hungry more deeply down range.

This has all been happening in real time, with recent disaster relief efforts, and what we would now like to do is to engage with the EO community to explore and see how we can collaborate between our sectors to leverage these exciting new synergies.

JAMES YOO *What are some of the obstacles to implementing your vision?*

HARTSHORN There are many moving parts. Everything that I just said is a lot easier to say than it is to do. One of the big challenges that we have seen is simply getting doors opened that have been closed or further opened that are only cracked. That is between the centers, the stakeholders, variously, who have a role to play in disaster preparedness and response. For example, the military and humanitarian organizations are often among the first on the scene when a disaster occurs. However, traditionally, those two sectors haven't talked to each other. That has prevented coordination that would enable elimination or, at least, reduction of redundancies, and it would optimize the response effort.

That has begun to change. These humanitarian organizations have, at some significant level, begun to set aside their reservations and to provide higher levels of awareness of what their priorities and strategic plans are and how they operate, so that these things can more fully inform the way that the military entities are engaging in the response efforts. Local responders (fire, police) and national emergency response agencies have begun to engage more fully than ever before with external first response entities, in an international context.

> "What we would now like to do is to engage with the EO community to explore and see how we can collaborate between our sectors to leverage these exciting new synergies."

Also bear in mind that the emergency management sector itself is, in the long term, relatively new. It didn't even really exist as a discipline until a couple of decades ago. So, everybody is making this up as they go along and what's exciting is that we are seeing closer coordination, globally, nationally, and at the regional level, where all stakeholders are being brought into the room, in varying degrees, to leverage, to coordinate, to optimize, to reduce redundancy, and so forth.

JAMES YOO *What are some upcoming opportunities to increase the collaboration between the VSAT and EO communities for disaster preparedness and response?*

HARTSHORN I've been in the satellite communications industry for more than 20 years and I will confess, fully, that over those 20 years, I have thought of myself as a professional of the satellite communications industry – full stop. I have seen the EO sector as being over a fence and this delineation becomes even more crystallized because you have industry associations and conferences that are focused on SatCom and those that are focused on EO. The difficulty of getting dialog going and coordination across those fences has limited the types of discussions that occur in the disaster preparedness effort.

We want to take those fences down and begin more full engagement and dialog. At Satellite 2018 on March 12-15, 2018, in Washington, D.C., we are looking to have the next in a series of discussions to take that dialogue to the next level.

What is the Value of the "Megaset"?

Famed venture capitalist Marc Andreessen famously said in 2011 that "software is eating the world."[1] He was referencing the fact that all industries are going through digital transformations and either you are in front of that tidal wave or you will be doomed to be swept away by it. His comments are largely seen as prescient and many traditional industries from automobiles to aircraft engines and of course your local taxi service have been disrupted by software applied to their datasets.

The Economic IMPAC

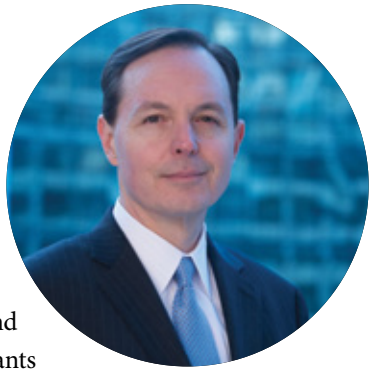
Space is no different of course but what is unique is that space-based data not only is a mechanism to disrupt the space industry, it is in fact that Trojan horse that will allow the entire global economy to be impacted. Why? Because space is less of an industry and more of a "domain" and its impact to all industries will be many trillions of dollars.

To understand better this point, it is best to understand the scope of the problem. The global economy sits at roughly $80 trillion[2] and is growing at roughly 5% per year. Within that economy are massive inefficiencies, from scrap in the supply chain, to bottlenecks with transportation, to unforecasted weather changes, to surprises from emergent phenomena we don't fully understand such as hyperinflation, economic collapse and even chronic unemployment. It is hard to imagine that the global economy couldn't be made more efficient by 10% or more with better information. This is where the space domain and the data it generates come into play.

EMERGENCE OF THE MEGA DATASET

With an estimated 8,000 small satellites planned for launch in the next 48 months, not only will there be a torrent of space-based data, the data layers will be new and novel. We will have all forms of optical data, synthetic aperture radar (SAR) data, infrared data, space debris data, weather data, etc. With all the various data layers, we will have a true multi-layered, hyperspectral dataset of the earth for the first time.

This will be supplemented by the explosion of earth-based sensors from the Internet of Things (IoT) transformation. This will turn literally every device with a microchip into a potential sensor. These data sources will be supplemented with drone-based data and data generated from "smart" buildings and "smart" city initiatives underway globally. All this will lead to datasets that will allow for insights we have never been able to create before—the so-called "megaset." This will truly revolutionize global commerce and its economic impact will be vast.



DYLAN TAYLOR

WHAT IS THE MEGASET WORTH?

If we define the megaset as ubiquitous, persistent, multi-layer, hyperspectral information, then we can ask ourselves, what is that dataset worth?

Taking a step back, if you think about current analogs of companies built on large-scale datasets the most obvious one would be Google. Google has essentially built a $700 billion market capitalization company by organizing, structuring and in some cases creating known terrestrial information. The key words here are "known" and "terrestrial." In addition to traditional search, Google's scope ranges from indexing and digitizing books, to indexing and rating restaurants to mapping the world, including real-time traffic data. Google's market cap went exponential once their data-based investment theses were known.

The megaset is a much larger opportunity. Why? Because of the sheer amount of data and the potential wisdom that can be extracted from that data. With the advent of artificial intelligence (AI) and machine learning (ML), the ability to make predicative observations and have "emergent" knowledge be created from large

T of Space-Based Big Data

DYLAN TAYLOR / CO-FOUNDER / SPACE ANGELS AND SPACE FOR HUMANITY
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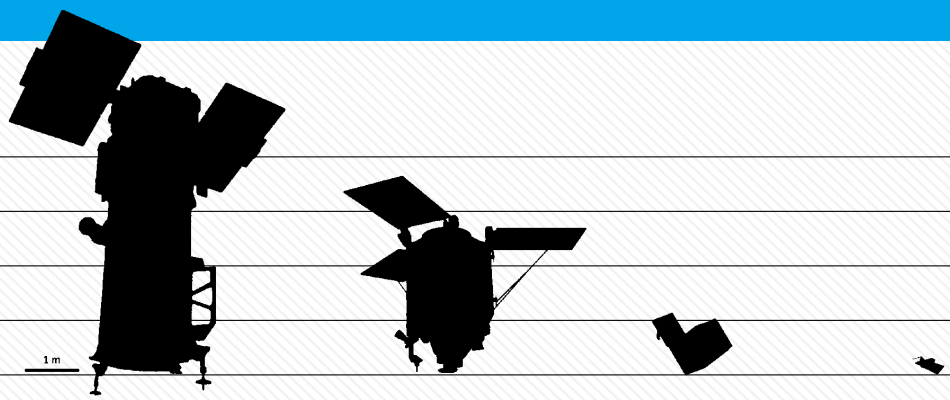


	WorldView-3	Pleiades-1A	SkySat	Dove
OPERATOR:	DigitalGlobe	CNES/Airbus D&S	Planet	Planet
CONSTELLATION:	N/A	4	24**	100**
WEIGHT:	2,800 Kg	940 Kg	120 Kg	5 Kg
INSTRUMENTATION:	Multiple spectral bands + SWIR	Multiple spectral bands + near-infrared	Optical and near-infrared spectral bands	Optical and near-infrared spectral bands
SPATIAL RESOLUTION:	0.3-3 m*	0.5-2 m*	~1 m (+1080p HD Video)	3-5 m

*Depending on spectral mode
**When fully operational

THE SWARM COMETH

How They Measure Up To Their Larger Brethren

MARKET TRENDS

> "From there, I would expect products and services leveraging space-based data to skyrocket and the value that accrues to the global economy to be profound. This will likely lead to the first multi-trillion dollar market cap company on Earth."

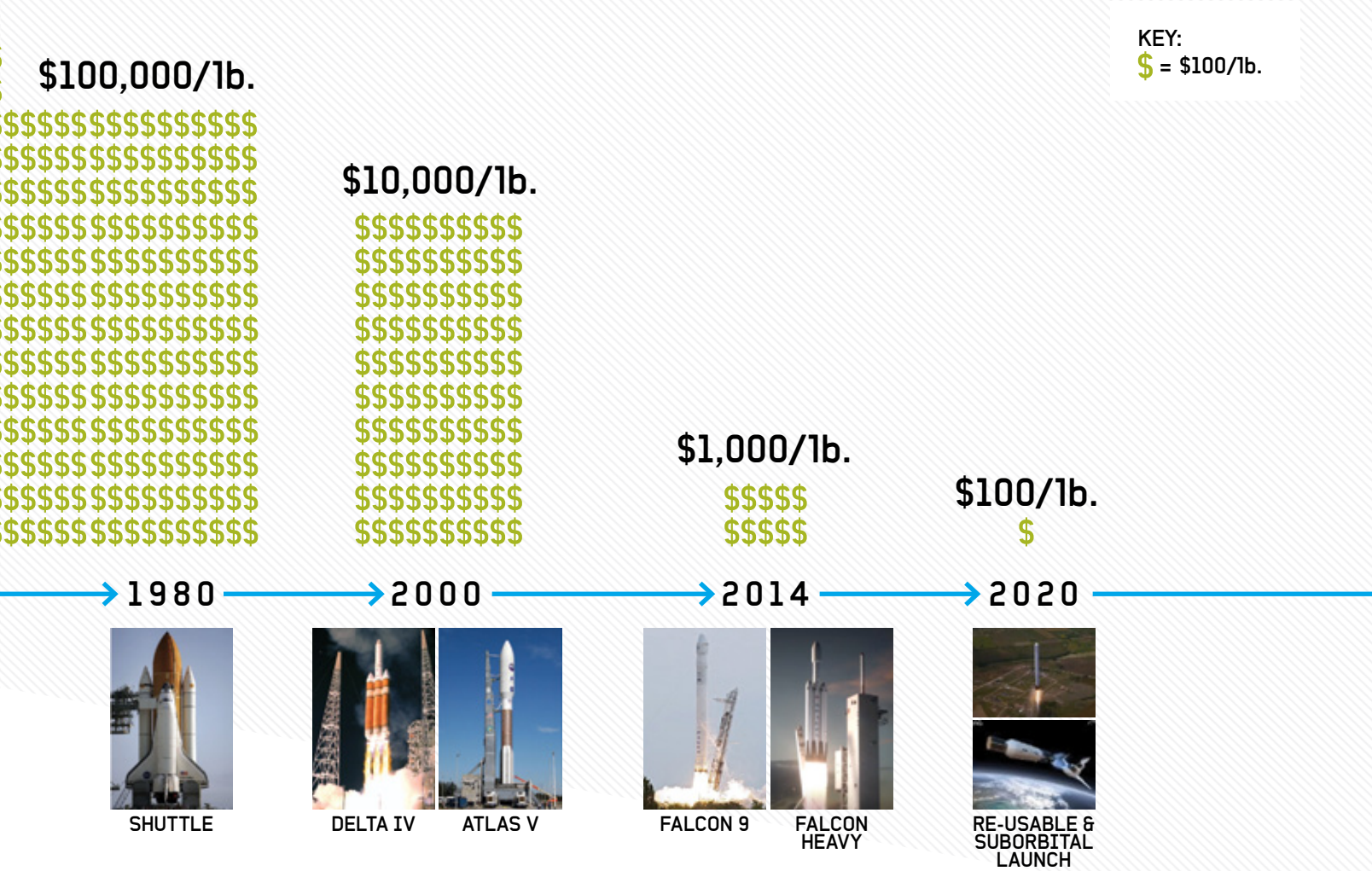
amounts of unstructured data is more powerful than we have even begun to realize. Very simply, the currency of the global economy going forward is datasets and the earth observation dataset will dwarf by orders of magnitude, in terms of scale and value, the dataset upon which Google has built their business.

The end state, the pot of gold at the end of the rainbow, that the capital sources investing in Earth observation are betting on (and this is why we have seen the many billions of dollars flow into the industry by the venture capital community and why space set a new capital flow record in 2016 from the venture capital community) is actionable data analytics. Think of it as analogous to the early investments in ecommerce, not necessarily knowing which storefront would emerge as the biggest winner but knowing that the opportunity would be a tidal wave of value creation. From this point of view, the interest in small satellites is not only justified, it may be undervaluing the opportunity.

In addition to the huge upside potential, space-based data is relatively capital-efficient, given the magnitude of the value it creates. True, it is capital-intensive to build a constellation and launch it into space, but with those constellations, now subject to Moore's Law due to the availability of higher launch cadences and lower costs for off-the-shelf electronics as well as launch, the costs are decreasing while the value of the data that they generate is arguably increasing.

THE FUTURE STATE

So how is this all likely to play out and what are the opportunities for specialists in the field? If standard industry dynamics hold, there will first be a plethora of constellations for each available data layer (optical, SAR, etc.). We are already seeing the early stages of this with many new company formations in the past 24 months. This will inevitably lead to winners and losers and ultimately consolidation within a data layer, with one large firm emerging for each. From there, I would expect a large data aggregator such as Google, Amazon or Facebook to enter the industry and consolidate the winners of each data layer. Data analytics powerhouses that have AI and ML expertise are likely the ones best positioned to take advantage of the massive potential of the dataset. I would expect all of this to play out in the next 36 to 48 months.



From there, I would expect products and services leveraging space-based data to skyrocket and the value that accrues to the global economy to be profound. This will likely lead to the first multi-trillion dollar market cap company on Earth.

The opportunities for those in the space-based data field are expansive. The best bet would be to focus on a specific data layer and ensure absolute mastery in how best to collect, aggregate, and mine that data. The next phase might be more interesting, however, which is to understand better "emergent" knowledge from multiple data layers.

Some examples of this could be global transportation bottlenecks leveraging both optical and SAR, and weather forecasting using space-based data and Earth-based sensors leveraging the IoT. The key focus in all of this will be the predictive nature of the insights. Once space-based data moves from telling us what has happened to telling us what will happen, the value creation will increase by orders of magnitude.

CONCLUSION

Space-based data will revolutionize not only the space industry but the global economy as a whole. Since space is a domain-based investment thesis, venture capitalists are flocking to the industry as they realize a global economy made even moderately more efficient is a multi-trillion dollar opportunity. As data layers become more refined and then hyperspectral, and as large-scale AI and ML technology is leveraged by a large industry consolidator, the benefits of space-based data and its products and services will accelerate dramatically. This will literally transform the earth and may be an even bigger space legacy than global telecommunication.

Endnotes:

1. https://a16z.com/2016/08/20/why-software-is-eating-the-world/
2. https://en.wikipedia.org/wiki/world_economy

Compani
MACHINE
for

Predictive Analytics for Crop Yield via API

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LEARNING
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◀ **FIGURE 1.** Hawaii in true colour, courtesy of Astro Digital

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The shift in the Earth observation (EO) market from selling pixels to selling finished intelligence products has sharply accelerated in the past couple of years, due to two factors. First, satellite imagery has become commoditized, partly due to the launch of dozens of small satellites. Second, advances in artificial intelligence, cloud computing, and cloud storage have greatly expanded the number of people who can access sophisticated analyses of this imagery or run the analyses themselves.

For this second installment in this new series on geospatial analytics, I discussed these developments with:

- Fritz Schlereth, Head of Product at Descartes Labs;
- Bronwyn Agrios, Co-Founder and Product Manager at Astro Digital.

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Descartes Labs

FRITZ SCHLERETH
DESCARTES LABS

ORIGINS AND COLLABORATIONS

Descartes Labs was founded by a group of former Los Alamos National Lab scientists who had been working for a long time with very large datasets, including geospatial datasets and satellite imagery. While these datasets were becoming more and more prevalent, Schlereth explains, these scientists were often hamstrung by the technology to which they had access. "They were not able to quickly scale up computer resources to deal with these large datasets and develop machine learning algorithms that would automatically cleanse and prepare the datasets for scientific analysis," he recalls. "They were also not able to make these data available to others for large-scale analysis."

So, they left the lab, started a company, and set about building that capability. Schlereth is responsible for bringing the company's technology to the market, including its platform and datasets, as well as its relationships with customers and the services it provides to them.

From its inception, Descartes has partnered with teams at Los Alamos National Lab that use its platform. It has also been working with researchers at universities and plans to expand its network in that area.

DATA AND ALGORITHMS

Descartes' imagery archive consists mostly of a collection of public datasets. "We work a lot with Landsat, MODIS, Sentinel-1, Sentinel-2, and Sentinel-3," says Schlereth. "We are getting Sentinel-5 online as well. We have Sentinel 4 on our roadmap along with dozens of other pubic and commercial datasets." In addition to geospatial datasets, the company also collects weather data.

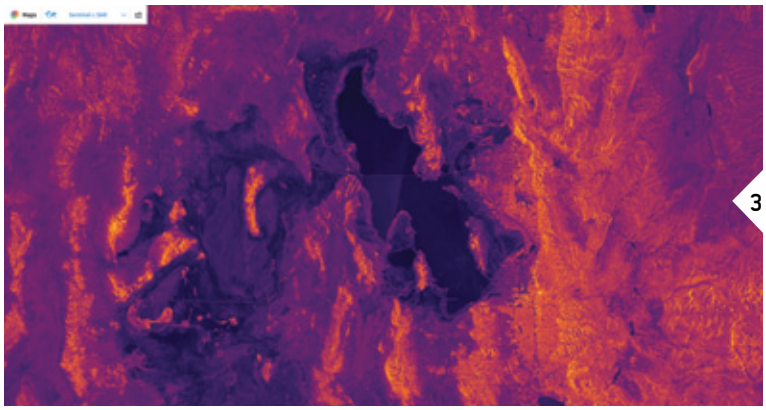
Besides housing that imagery, the company prepares it for scientific-grade analysis by converting it to surface reflectance and by co-registering datasets and rationalizing them with respect to each other. "We work hard to make sure that, within a single analysis, we are enabling the scientists to pull from all the different data that are available," Schlereth explains.

The company has also introduced its own derived datasets, as well as pre-packaged algorithms that give scientists shortcuts, such as water maps. "We make it easier for users to focus on a deep learning application, such as object classification," Schlereth says. "We already have some of our own, pre-trained classifiers that they can use for that."

PLATFORM AND SOLUTIONS

Descartes has created a computing environment that is easy to use and accessible to scientists, most of whom are not experts in cloud engineering, though they understand the cloud's importance to their work. It has built a technology platform and put public APIs in front of its data archive and in

◀ FIGURE 2.
Wind turbines found visually in North America using computer vision with Descartes Labs GeoVisual Search



▲ FIGURE 3. Synthetic Aperture Radar (SAR) over North America from ESA Sentinel-1, courtesy Descartes Labs

front of many of its tools. Some of its customers, in business and academia, use its platform similarly to how they use Google Earth Engine (GEE), for example, to do their own analysis and solve their problems.

Meanwhile, its internal science team provides services for customers that lack their own capability to use its platform. "Essentially," Schlereth explains, "our science team uses our platform in the same way that an external customer would to solve a problem in, say, agriculture or energy. We have both a platform business and a solution business."

In the geospatial world, Schlereth points out, the term 'platform' is used to describe many types of offerings. "GEE and DigitalGlobe's GBDX are examples of platforms that are similar on the surface to what we've built. However, it is important to emphasize that we've focused on machine learning as a primary purpose of our platform, and that informs the architecture and design decisions that we've made." So, while acknowledging similarities between GBDX and Descartes' technology, he sees DigitalGlobe first and foremost as a partner. "Certainly, their high-resolution dataset is an incredible resource. However, I also see opportunities for joint customers where we can provide advanced analytics in domains such as agriculture, where we may combine different data sources from different public and commercial sources."

To that end, Descartes creates a synthetic layer from the electro-optical data that it pulls, and processes it for surface reflectance. It also creates its own cloud and cloud-shadow layer and co-registers its datasets so that features on the ground are mapped consistently across all of them. "The end goal of all of that is to make it very easy to the researcher to incorporate different datasets for the same problem," Schlereth says.

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>
> *–FRITZ SCHLERETH*

PROCESSING

Many of Descartes' projects rely on either traditional remote sensing-based approaches, such as developing a yield model for crops by measuring the spectral signature of each pixel and then using linear regression; or on deep learning, for example, mapping the power grid and quantifying wind or solar power production. "Some buyers essentially buy access to our platform and do their own work, while others buy a ready-to-use solution. Perhaps the most powerful option is for the customer to buy both a solution and license platform access. For example, a customer can buy a map of power infrastructure in SE Asia and use it in a model they build for themselves using our platform."

Images collected on different days by different sensors are often hard to compare, due to slight differences in atmospheric conditions and in the

behavior of the sensors. To ensure its data users that they can compare a pixel collected on one day by one instrument to a pixel collected on a different day by another instrument, Descartes cleans and calibrates optical data and provides a top-of-the-atmosphere product for all of its datasets, as well as a surface reflectance product. It also strips out clouds and cloud shadows, because many instruments do not already mask them. "To make it easy to work with the data, we wanted to provide our own, consistent cloud mask across our imagery collections," says Schlereth.

Descartes also works quite a bit with synthetic aperture radar (SAR) data and makes it available to users of its platform. "We've made it easy to combine SAR with optical data so that the user can stack different raster layers for use in the same analytic or machine learning process," Schlereth says.

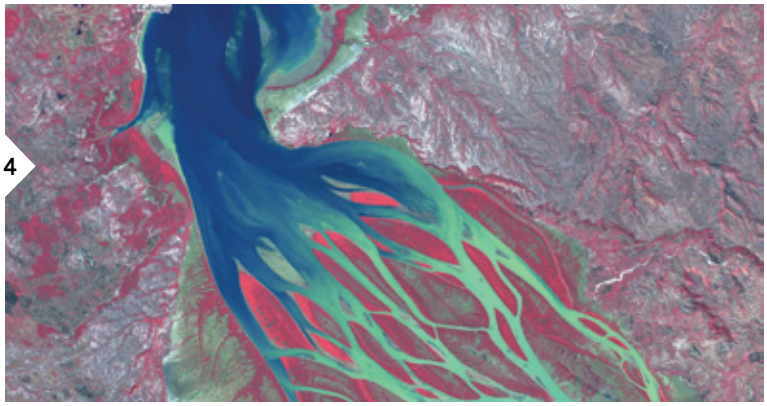
USE CASES

Many researchers use multiple satellite imagery and geospatial analysis platforms. Descartes' users tend to be scientists, some working in commercial fields, such as agriculture and energy, and others at research institutions. "Our use cases tend to be heavy on the machine learning side," says Schlereth. His company provides both solutions for specific industries and business needs—such as agriculture models, land cover maps, and production facilities monitoring—as well as tools that allow research teams to develop those analytics themselves. "Between those two extremes, we've also built a series of more generalized components, such as water maps and forestry layers. We also do a lot of object detection."

Descartes has prioritized agriculture, energy, and industrial production for steel and other kinds of industrial products, and is building several layers that relate directly to those applications. "Our goal is to produce a broad and deep collection of layers that are useful for geospatial analysis, such as maps of where water is, or more abstract ways of processing," says Schlereth, "such as, different NDVI products that are already processed and ready to be used, primarily for agricultural analysis." The company's users can work via an API with both processed imagery and derivative datasets, such as measures of air quality or crop maps. "They can pull these derivative datasets into their own systems or develop more sophisticated models using our derivative datasets as an input."

Besides agriculture, energy, and industrial production, Descartes also has projects in other areas. "A lot of this boils down to understanding regional or global supply and demand around a commodity," Schlereth explains. "In agriculture, the best example is understanding grain supply and what fields are likely to produce, or how animal populations and feed demands are changing over time, or how a transportation network moves that commodity."

With respect to energy, he points out, the company focuses largely on production, demand, and infrastructure. "Often the question is 'What is power demand going to be because of some weather condition?' We can also look at the change that alternative energy generating sources have introduced into the system, such as the growth of solar and wind power."



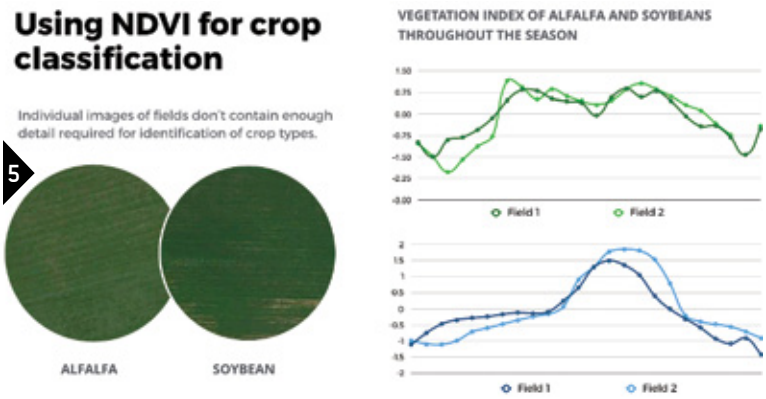
▼ FIGURE 4. River delta in Madagascar in false colour, courtesy of Astro Digital

Astro Digital

ORIGINS AND COLLABORATIONS

The backgrounds of Astro Digital's founders include mechanical engineering, mapping, business, and physics: Chris Biddy, the company's CEO, has been building cubesats his whole career; Agrios worked for years at Esri and also at Planet; and Mikhail Kokorich, the company's business manager, is an entrepreneur with a physics background. "We know that designing a satellite system for the sake of designing a satellite system is not going to get us into a good place with customers," says Agrios. "It is about identifying the changes in the market, building software, and

BRONWYN AGRIOS
ASTRO DIGITAL



▲ **FIGURE 5.** Astro Digital imagery allows for the creation of vegetation indices (NVDI -Normalized Difference Vegetation Index)

designing satellites to answer those questions that are in the market."

In developing its analytic capabilities, Astro Digital collaborates closely with the National Snow and Ice Data Center and the Laboratory for Atmospheric and Space Physics, both at the University of Colorado at Boulder. These centers' skillsets range from building satellite calibration systems and operating satellites to atmospheric science and remote sensing.

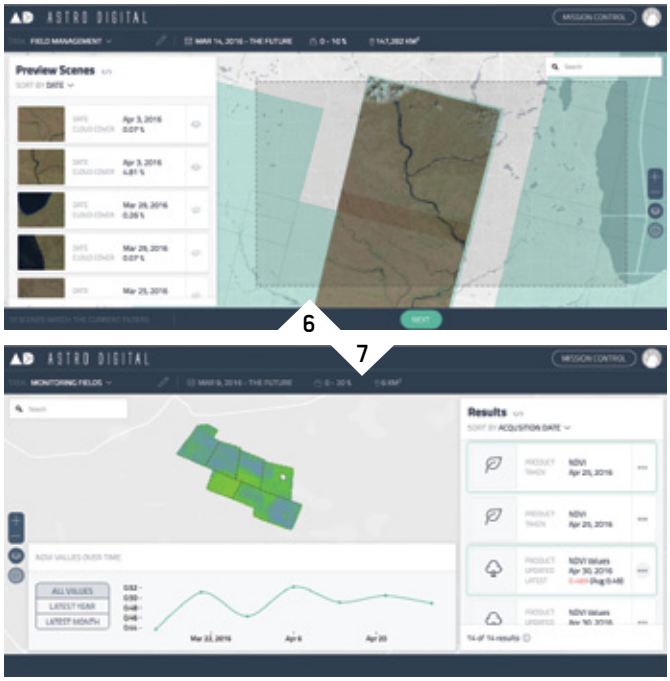
THE BET

Treating smallsats like large ones misses the point and erodes their value, Agrios argues. Instead, they should be purpose-built and integrated into a system that can ingest the pixels they collect, analyze them using computer vision and machine learning, identify changes and trends, and answer scientific and business questions. This is facilitated by the coverage and refresh rate that swarms of smallsats enable for a fraction of the cost of legacy satellites. "We are producing reliable coverage and high-quality imagery," she says.

Astro Digital began by focusing on the information needs of commercial agriculture, including commodities trading and supply chain management. "Four years ago," Agrios recalls, "we made the bet that companies would be more open to accepting information based on computer algorithms and that cloud computing would be increasingly low cost." So, the company decided to build a system with a 22-m resolution to capture "deep stacks of pixels that can be ingested into a machine learning system." The focus on computer vision guides the company's choices, from its sensors' resolution and spectrum to the filters used on its spacecraft to how it downlinks the data. "It is not the resolution or the frequency that set us apart. It is the fact that this is a system-based approach to build for a next-generation remote-sensing system that relies on machine intelligence."

THE BUSINESS MODEL

"Nobody is buying imagery anymore," Agrios points out. "Nobody will be buying imagery anymore. They will be buying a subscription to an API and have imagery show up right in their application. This is a disruption in the business model that is being fueled by small satellites." Sophisticated customers, who have a significant investment in a remote sensing pipeline, access images from the API, then process it and analyze it themselves. "Market growth happens when customers access information about their areas of interest where processing and information is handled within the Astro Digital environment," she explains.



▶ **FIGURE 6-7.** Making maps and results screens from Astro Digital

Astro Digital's customers subscribe to specialized products—for agriculture, disaster management, etc.—that the company keeps refining over time with feedback from them, but does not customize for each customer. "Our goal is to provide a suite of products and not be a services company," says Agrios.

THE CONSTELLATION

Astro Digital plans for its Landmapper constellation to be fully operational by mid-2019. It includes

both the Landmapper-BC, for broad coverage—a moderate-resolution imaging system that will provide daily global coverage—and the Landmapper-HD, for high definition. The company launched the first Landmapper-BC satellite in mid-January and will begin launching the Landmapper-HD in the third quarter of 2018. It will take the constellation 18 months to be complete and operational, from the launch of the first satellite. This includes both launching all satellites and commissioning them (the time it takes to bring them to operational status).

◀ **FIGURE 8.** Agriculture Dashboard of Astro Digital

▼ **FIGURE 9.** Agriculture in Italy shown through the near infrared spectrum, courtesy Astro Digital

Creating a high-quality, well-calibrated set of pixels to ingest into the analysis enables Astro Digital to identify features, calculate trends, and detect meaningful change, Agrios explains. Depending on the problem, the analysis can range from regression analysis to examine the relationship between variables to training a neural net to learn from a series of observations.

A commodities trader, for example, may need to assess the yield of a crop, to know how much of it is going to be harvested. "What we can do is create something like a crop classification signal, which can tell you, on a global scale, whether a pixel is corn," says Agrios. "We can tell that to you very early in the planting cycle because we have not only a recurrent neural network that is trained to carry out that very specific task, but also a large archive that goes into defining that. We are looking for specific signals that get used to help inform somebody else's answer."

The company has researched how to use neural nets and multi-source moderate-resolution imaging to do early classification of crop types and is constantly trying to improve the quality of its input images. This includes using machine learning to detect cloudy pixels. Building an autonomous analytical system to do this, Agrios points out, requires the image quality to be as close to perfect as possible.

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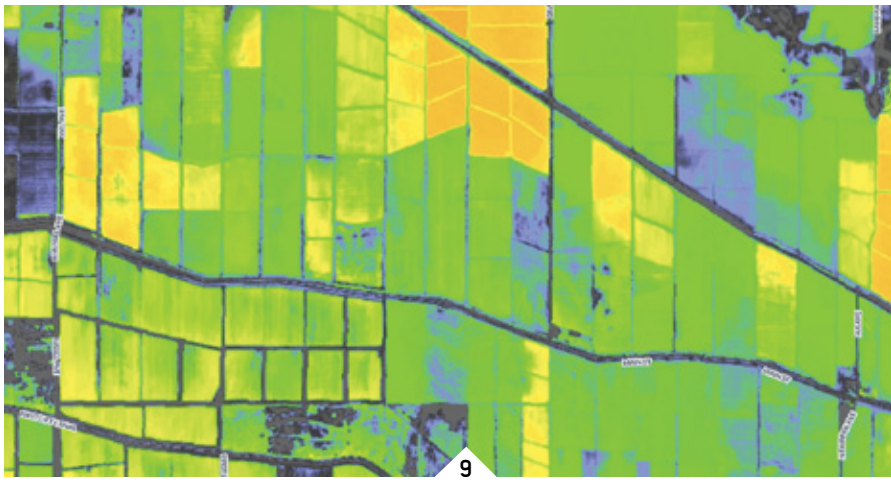
> – *BRONWYN AGRIOS*

CONCLUSIONS

While Astro Digital has its own satellites and Descartes does not, both Descartes and Astro Digital go beyond collecting EO data to prepping it for ingestion into and analysis by a system. Both companies provide their data and analyses in a wide range of formats, depending on each customer's specific needs and levels of technical sophistication. They are two of a growing number of companies that are taking full advantage of advances in the collection and machine-processing of EO data to address complex business and scientific questions.



INTEGRATED UAV & LIDAR SOLUTIONS

Applications from Utilities and Oil & Gas to Autonomous Vehicles and Mining

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

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LiDAR has been around since the early 1960s. In recent years, it has emerged as a key geospatial remote sensing technology: aerial and ground-based scanners are used routinely for mapping and to produce 3D models of cities, LiDAR is an essential sensor for autonomous vehicles, and some units are now light enough to be carried by small UAVs. Most uses of LiDAR sensors require tight integration with the platform on which they are mounted. Therefore, some LiDAR manufacturers are partnering with UAV manufacturers to produce and sell complete solutions for specific end uses, such as precision agriculture, corridor mapping, or bridge inspection.

At the end of September, YellowScan, which designs, develops, and produces UAV mapping solutions for professional applications, and Quantum Systems, a spin-off of the Technical University of Munich, launched a turn-key LiDAR UAV solution. It combines the former's Surveyor LiDAR sensor and the latter's Tron vertical takeoff and landing (VTOL) platform, which can fly up to 90 minutes and, therefore, cover large areas. According to the two companies, the UAV is designed for surveyors who need "a robust and easy-to-use LiDAR solution" with quick data processing. The Tron's remote controller guides it automatically, but allows the operator to override the program in an emergency. The platform's vibration dampening and secure housing protect the sensor.

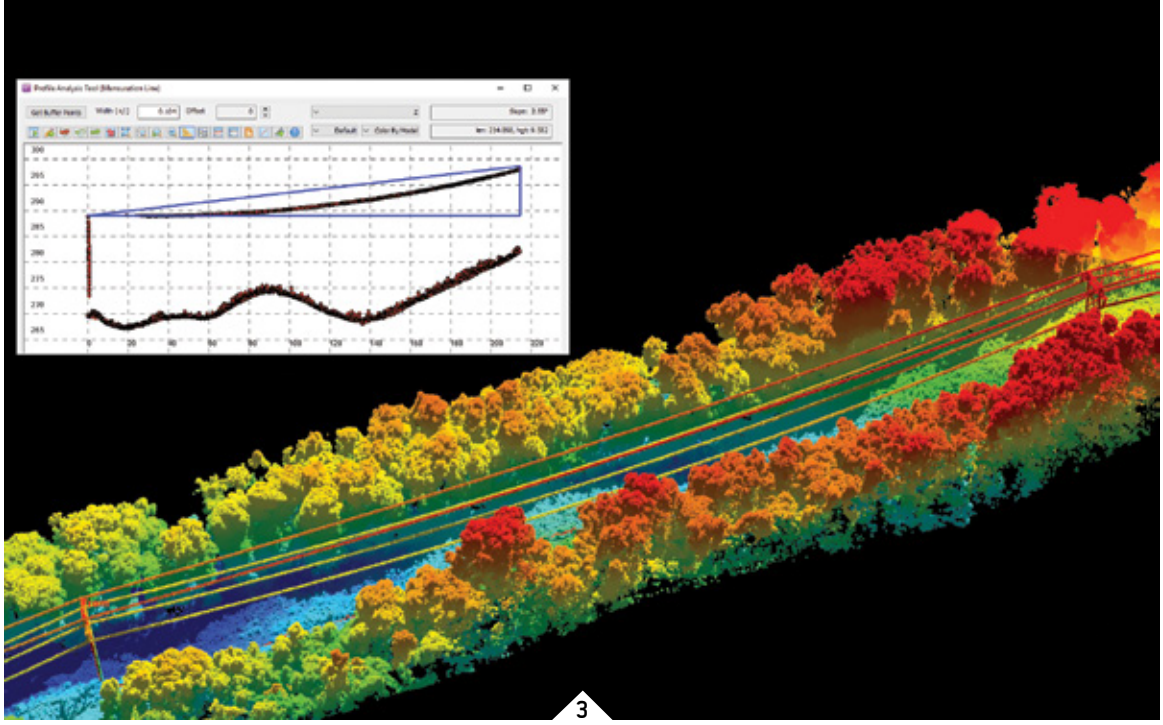
At the beginning of November, Velodyne LiDAR Inc., a manufacturer of 3D vision systems for autonomous vehicles, and BoE Systems, a geospatial systems integrator, launched a solution integrating the former's VLP-16 Puck and Puck LITE 3D LiDAR sensors into the latter's UAV fleet for geospatial data collection and analysis. The solution provides 360° imaging for industries that need quick, safe, and accurate aerial inspections,

"VTOL's time is coming. There are only a few companies in the world that can master flight beyond line-of-sight and most small UAV companies are just assemblers, not developers. Quantum is a developer. So, in this sense, we think that they have a good solution."

—ROBERTO CASINI, YELLOWSCAN

◀ **FIGURE 1.**
Velodyne's VLP-16 "Puck" LiDAR sensor mounted to a UAV from BoE Systems.

▶ **FIGURE 2.**
With the large numbers of turbines in wind farms, UAV-mounted LiDAR sensors can replace expensive manpower needed for regular inspections. Image courtesy Velodyne.



▶ FIGURE 3. A point cloud of a power-line segment scanned using the BoE Systems ELV-16 Scanner. Measurements highlight the powerline sag, slope, length, and height above changing terrain. Not shown are the lateral measurements from vegetation encroachment. Courtesy BoE.

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including transportation, utilities, telecommunications, infrastructure, construction, forestry, and agriculture. BoE Systems acquires the imaging data, processes it, and produces analyses and inspection reports. Its hardware and software integrations also provide digital maps that can be used to produce, among other things, flood models, drainage analyses, Building Information Modeling (BIM) files, and contour mapping.

PARTNERSHIPS

YELLOWSCAN & QUANTUM SYSTEMS

"We have customers in anything that requires airborne LiDAR—including archaeology, geology, filming, topography, corridor mapping, inspections, oil & gas. You name it," says Roberto Casini, YellowScan's Regional Sales Manager. "The LiDAR is a pretty generic horizontal platform. We have three (soon to be four) products that are specialized in terms of precision and accuracy, for different prices. Basically, all of them can be used in all of these segments."

YellowScan integrated Quantum System's Tron with its Surveyor sensor to address a key concern in the integration of LiDAR into UAV, which is weight. At only 1.6 kg, Casini says, "the Surveyor is the lightest in the market, as far as we know. We are currently demonstrating the integrated solution to several customers in Europe and around the world, and participating also in some tenders."

YellowScan has a two-legged expansion strategy, according to Casini. One leg is to work with top geomatics dealers. "We just signed with two Trimble dealers in Finland and in Sweden," he says. "We are pursuing these Tier 1 dealers because we believe it is a better fit with dealers of technology that's related to imaging, more generally speaking, and mobile scanning in particular, but also indoor scanning." The other leg is to work with UAV manufacturers because you cannot develop a UAV LiDAR without a UAV. "We are pretty agnostic on this, in the sense that we do not sell any drones, but are certifying drones that are tested with our products."

His company, Casini says, is currently using three laser head suppliers: the German IBEO for its Mapper II, which is its entry-level product; Velodyne's VLP-16 for its Surveyor, its top-selling product; and Riegl for its high-end products.

Casini also speaks highly of Quantum. "I would say that among VTOL manufacturers in the world, they are maybe one of the most industrialized. They are very professional people, with a young and aggressive team of engineers and now a new sales person with long experience in remote sensing. So, they are doing a very good job and we are fitting very well together."

Quantum differentiated itself from similar companies by developing its own flight control unit and software, Casini says. "For several professional applications, this is sometimes a must, particularly when you are dealing with government contracts. Besides that, they have a very slick product. Among

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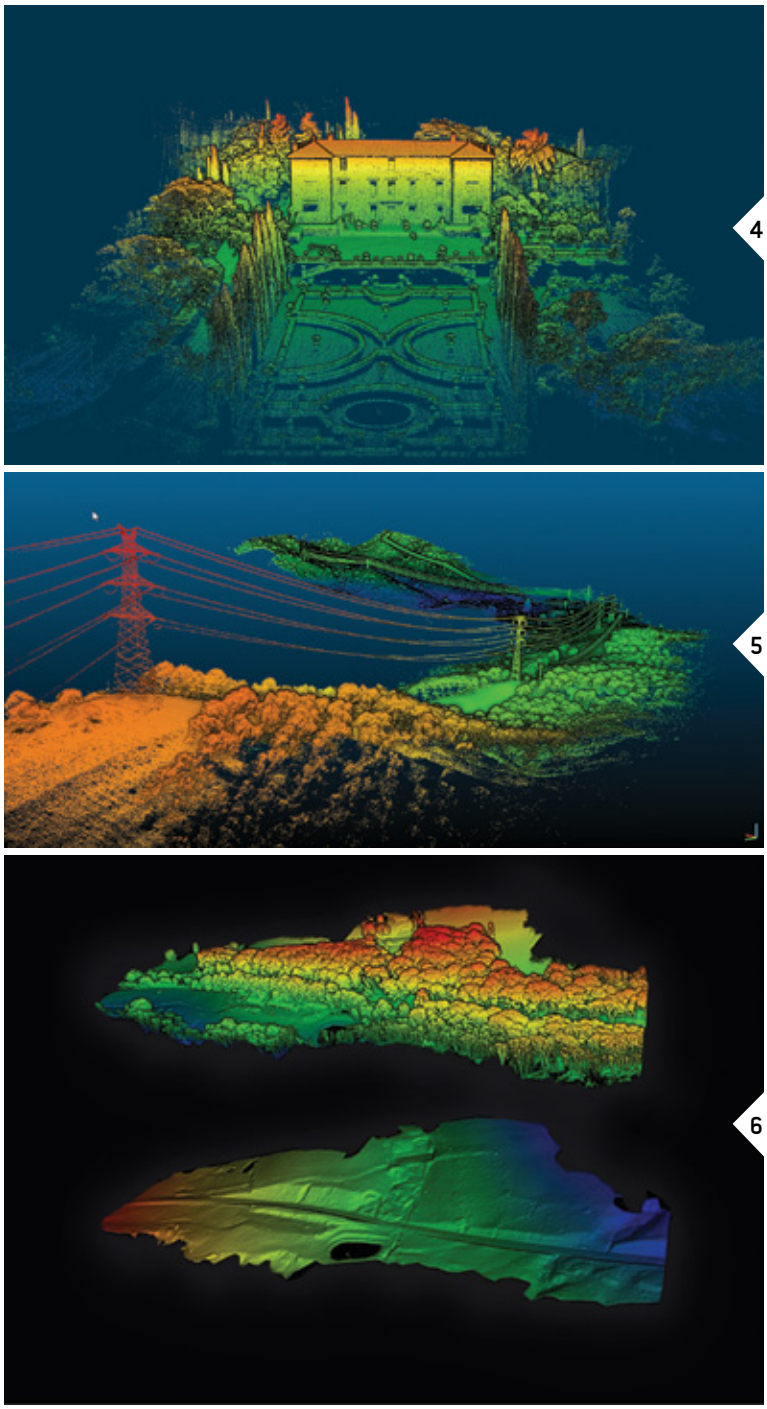

▲ **FIGURE 4-6.** LiDAR point clouds courtesy of YellowScan

their competitors you can find more garage-type products, but they really have something industrialized and ready for mass production."

YellowScan decided to work with Quantum in large part because of the latter's ability to adapt payloads to their machine, says Casini. For example, he recalls, the Tron was originally conceived for photogrammetry, using cameras like the Alpha 6000 from Sony, but it was not well-balanced because the camera was very light. By integrating YellowScan's Surveyor LiDAR and positioning it in the nose of the aircraft, Quantum was able to optimize the UAV's attitude. "They demonstrated very good skill in this integration," says Casini. "Of course, we are just a payload, so we don't have any say on what the UAV should look like. The complete solution must be one of the coolest on the market today."

VELODYNE LIDAR & BOE SYSTEMS

Frank Bertini, UAV & Robotics Business Manager at Velodyne LiDAR, Inc., notes, "Most of our partners are our customers," including YellowScan. BoE

▼ FIGURE 7. The use of UAV-mounted LiDAR sensors saves time and money for critical utility tower inspections. Image courtesy Velodyne.

▶ FIGURE 8. LiDAR sensors from Velodyne can be mounted to UAVs for environmental and agricultural management.

approached Velodyne a couple of years ago about possibly integrating the latter's LiDAR on their drones, primarily for agricultural work. "We don't have a good presence in the Midwest and it is great to have people across the country, so BoE fills a nice niche for us: agriculture and the Midwest."

Besides providing the sensor, Velodyne supports BoE with repairs and questions about the LiDAR sensor, such as where it is advantageous to use it over another technology, such as radar or photogrammetry. "We are just a hardware provider for them," says Bertini. "They do most of the heavy lifting with the integration, getting all the sensors to communicate in the data fusion, and then working with the customers, to make sure that they are ultimately happy with the product."

For Velodyne, its partnership with BoE is about geographic coverage. "Our LiDAR sensor is not a solution; it is just a component," says Bertini. "We don't interact with the end users because it would take them a long time to integrate the sensor—and that is if they even had the prerequisite skills and the will to do it. Our partnership with BoE allows us to connect with those customers with a full solution."

Velodyne has similar partnerships with several companies, BoE being the newest partner. "In the United States we probably have about five of these drone integrator companies that will make these scanning mapping systems, which are pretty much all the same," says Bertini. "It is not anything autonomous or any of the fancier applications that we get involved with. It is just passive scanning over the environment. We have partners in Asia and all over Europe, such as YellowScan in France," as previously mentioned.

This partnership model, with an integrator solution provider that ultimately sells the solution to the end user, works well for Velodyne, Bertini explains. "Most people find us and do not really understand

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all the ins and outs of what it takes to get our sensor to do something useful. They might see a video or a spec sheet or hear some things from colleagues and think that you can just bolt the sensor to the bottom of a drone and you are up and running. It is a little more complicated than that."

REDUCING OPERATING COSTS

One of BoE's key uses for a UAV LiDAR system is corridor mapping for a utility company, monitoring the encroachment of trees onto power lines. To maintain their flight time, they bring along multiple battery packs, so that they can do quick swaps. Velodyne's sensor will reduce BoE's operating costs.

Velodyne recently halved the price of its VLP-16, from $8,000 to about $4,000. "The lower total cost makes the sensor much more accessible for a whole host of applications," says Bertini. Additionally, he points out, Velodyne's sensor is unique in that it emits 16 beams, each at a different angle, unlike most traditional LiDAR sensors that only have one scanning beam that hits the target perpendicularly. "With our sensor, at the top we have a +15 degree angle and then, on the bottom, a -15 degree channel. That allows you to almost see around objects. So, you get a lot more data points and at different incidence angles, which allows you to see a little bit more. Another advantage is that we can get dual returns, which allows you to see under the tree canopy, down to the forest floor or actually measure crop heights."

COMPARING GEOGRAPHIC MARKETS

With regards to regulation, the U.S. and European markets are "kind of watching each other," says Casini. U.S. manufacturers have the advantage of operating under a single set of regulations, he points out, while their European counterparts must contend with a host of different national rules. "The European Commission is attempting to harmonize the regulations, but there is a lot of friction between all the authorities as to which will have the last say."

Germany, which was late to specifying regulations

▼ **FIGURE 9.** The use of UAV-mounted LiDAR sensors saves time and money for critical telecommunications tower inspections, courtesy Velodyne.

but has recently sped up its rule-making, has a commission charged with testing flight beyond line-of-sight and proposing regulations. Currently, to fly a UAV beyond line-of-sight in Germany "you must almost be an airplane pilot," says Casini. It is hard to find pilots with such expertise. In other countries, the definition of beyond line-of-sight is looser. These discordant regulations have limited the adoption of UAVs and of LiDAR, he says, but the climate is improving.

LINE-OF-SIGHT

"VTOLs such as Quantum's have a big advantage, because they can take off from a 10 sq m surface and fly vertically, like multicopters, then become fixed-wing," says Casini. "This gives them at least four times greater autonomy than any multicopter that you can imagine." There are some applications, however, that require a very slow speed, lower than the 40 kph or 50 kph minimum speed of fixed-wing aircraft. "VTOL's time is coming," he says. There

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"As soon as the technology for flying them beyond line-of-sight is mature and national regulations allow it, demand for UAVs will hit its next inflection point. VTOL UAVs combine the best of rotary aircraft—the ability to take off and land from a tiny patch and to hover—with the best of fixed-wing aircraft—greater speed, which allows them to cover larger areas in the same amount of time."

are only a few companies in the world that can master flight beyond line-of-sight and most small UAV companies are just assemblers, not developers, he points out. "Quantum is a developer. So, in this sense, we think that they have a good solution."

While in Europe UAV flights beyond line-of-sight are not yet allowed, Casini believes that they soon will be. Quantum is already able to fly beyond line-of-sight, he points out, and is in discussions with the German authorities to get permission to do so. To take advantage of this coming capability, YellowScan will soon integrate a light LiDAR sensor with Quantum's Tron.

Where flight beyond visual line-of-sight is allowed, fixed wing UAVs make better use of LiDAR data, Bertini points out. "When you put our sensor on rotor craft, it almost spits out too much data," he says. "You hit the same point 10 or 15 times over. Fixed wing, where you are going a little bit faster and covering more ground, is more efficient and gives you higher value."

The nature of Quantum's UAV, which flies at 50 kph and at an altitude of 100 m, is optimal for such applications as corridor mapping, which requires flying for 20 km to 30 km over pipelines or power lines, Casini points out. "We also see applications for large areas of forestry, for example in Finland where you have to scan something like 200 hectars per day or more and you need to be high because the trees are around 40 m to 50 m high."

Its partnership with Quantum, Casini says, enables YellowScan to address the growing demand for flight beyond line-of-sight in Europe and in Asia, Africa, and South America, where regulations are a bit looser and the requirements are for mapping large areas.

NEW PRODUCTS

At the Consumer Electronics Show in Las Vegas in mid-January, Velodyne announced its VLS-128 sensor, which has 128 channels and a range of up to 300 m, almost triple the range of its previous sensors. "It is targeted mostly for the autonomous driving space, but it could be used on a drone, probably more of a high-end one, if a customer really wanted that level of performance," says Bertini.

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▲ FIGURE 10. Image courtesy of YellowScan

▲ FIGURE 11. The BoE Systems ELV-16 Scanner mounted to a DJI Matrice 600 Pro UAV, as seen from the front right of the UAV.

The company has also been working on a new product called Velarray, which "is just getting to the point where we can show it and start shipping it to customers," says Bertini. "I think it is going to be more interesting to the UAV space due to its small form factor. It is not a rotating sensor but a forward-facing sensor. So, if you fly it on a drone and point downward, you will utilize 100 percent of the sensor. Right now, our sensor goes 360 degrees and most users are not using 180 degrees of that. So, they are not really getting the full performance."

CONCLUSIONS

As soon as the technology for flying them beyond line-of-sight is mature and national regulations allow it, demand for UAVs will hit its next inflection point. VTOL UAVs combine the best of rotary aircraft—the ability to take off and land from a tiny patch and to hover—with the best of fixed-wing aircraft—greater speed, which allows them to cover larger areas in the same amount of time. By forging strategic partnerships, LiDAR manufacturers, UAV manufacturers, and system integrators are accelerating the development of the next generation of UAVs and positioning themselves to make the most of the new opportunities they offer. ∧o

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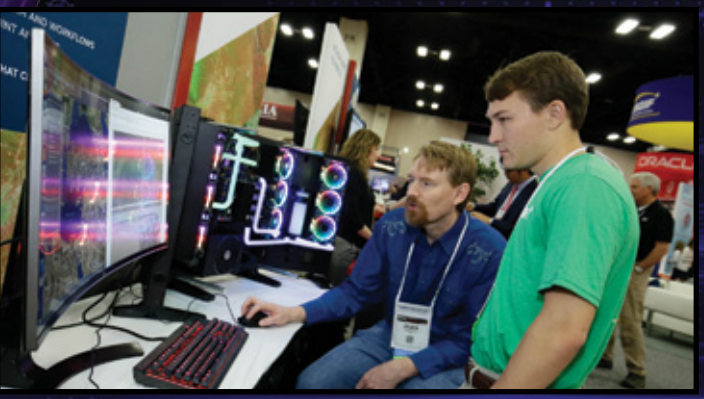

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