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Greg Bentley, Bentley Systems | **P 12**

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SMALL IS THE NEW BIG

Space is big. But, the satellites disrupting the earth observation market are getting smaller and smaller

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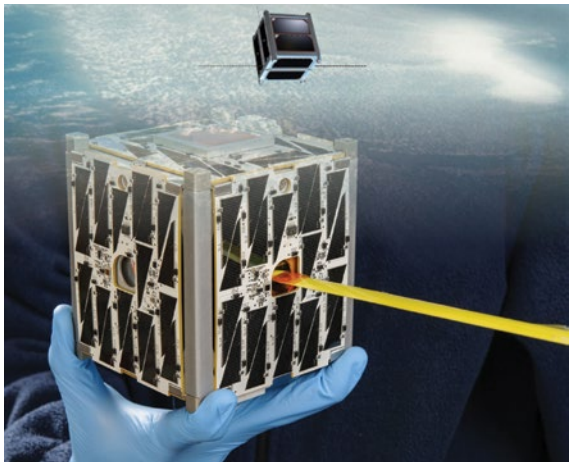

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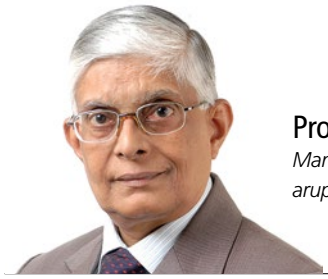


Prof Arup Dasgupta
Managing Editor,
arup@geospatialmedia.net

Smallsats open up a new approach to remote sensing

The term 'Small is beautiful', coined by the British economist E. F. Schumacher, is a call to empower people through simple but appropriate technologies. The term seems to have been given a new twist with the advent of small satellites which, when operated in a cluster or constellation, can mimic bigger satellites.

Small satellites draw upon two major technological advances. One is the miniaturization of electronics and the other is autonomous control which turns the satellite into a 'smart' satellite. Such satellites can fly 'in formation' required for a given task. For example, a region requiring rapid repeat coverage could have a number of similar satellites overfly the region at intervals of say a few hours. If the task is to cover a large swath, the satellites could then form an array across the flight direction. Autonomous control becomes easier because small satellites have small mass and therefore require low energy control systems.

Will small satellites spell the death knell for big complex satellites? Not quite. Big satellites will still be around for bigger tasks like centimeter-level precision imaging. They will also be needed for non-imaging sensors like scatterometers and for radar sensors like synthetic aperture imaging radars. Small satellites may present a potential headache in terms of orbit management as hundreds of them begin to orbit the earth. Being small they are also more vulnerable to space debris. Data policy in terms of access, reuse and archiving will also need to be revisited. Another potential area of conflict could be standards for imaging, formatting data and dissemination.

However, for the consumers, small satellites present a whole new world. Paucity of data will be a thing of the past. In fact, there will be better opportunities for deciding revisit rates, monitoring changes and tracking activity. Data overload may require curating of the data for specific purposes. This will open up a market for value addition where customers can outsource analytics support and buy specific information rather than basic remote sensing data sets. In short, small satellites could result in a totally new approach to remote sensing.

Hexagon buys GeoRadar to add to sensor portfolio

Hexagon has entered into an agreement to acquire Italy-based Ingegneria dei Sistemi's GeoRadar division. The transaction is expected to close during the second quarter of 2016.

IDS is a privately owned company with core expertise in radar-based solutions for multiple industries. Its GeoRadar division provides mining and geospatial industries with radar solutions for structural health monitoring and underground utility mapping. GeoRadar's structural health monitoring solutions enable engineers to remotely monitor movements and vibrations of the earth in real time. Its underground utility detection solutions provide engineers with dimensional information such as size and location of buried pipes and/or the health condition of roads and rail tracks through the detection of underground cracks and cavities.

Russia launches EO satellite after halted countdown

The Roscosmos State Corporation, the Russian space agency, has delivered the civilian-operated Resurs-P earth observation satellite into its targeted sun-synchronous orbit. The Soyuz 2-1B rocket launched the satellite on its second attempt, after the booster suffered a rare on-pad abort just about ten seconds prior to the initial launch. A pad abort during ignition is very rare for Russian rockets. This was the first on-pad abort for the Soyuz 2-1B and the first for any Soyuz rocket in more than a decade.

The Resurs-P satellite has been developed by the Progress State Research and Production Space Centre. The satellite's primary instrument is the Geoton-L1 panchromatic imager, which can image the surface at a resolution of 1.0 to 3.4 meters. Images can be transmitted to the ground in real time, using the Sangur-1U downlink system. The satellite is expected to update maps, aid the work of Russia's Natural Resources and Environment Ministry, Emergency Ministry, and the agricultural, fishery and hydro-meteorological agencies.

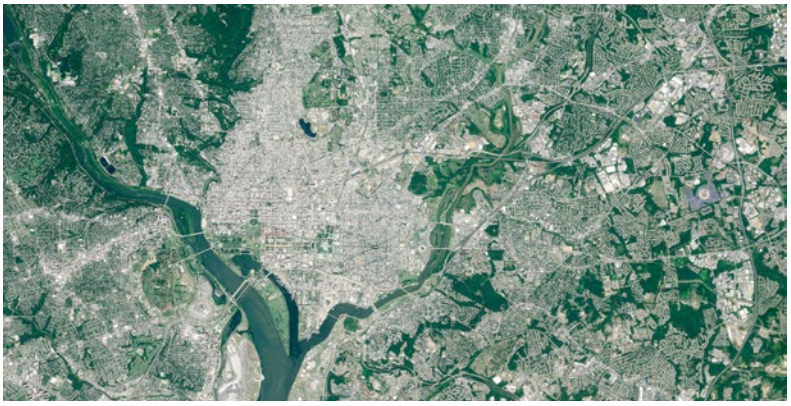
Resurs-P earth observation satellite

Courtesy: Roscosmos

ESA partners with US agencies for Sentinel data use

The European Space Agency has signed an agreement with US federal science agencies — NASA, the National Oceanic and Atmospheric Administration and the US Geological Survey — to make data from European Sentinel satellites available to them. This collaboration will cater to scientific and commercial customers who are interested in the current conditions of forests, crops, and water bodies across large regions and in the longer term environmental condition of the Earth.

The signed arrangement will allow NASA, NOAA and USGS to systematically retrieve the Sentinel data from a dedicated International Data Hub operated by ESA. These agencies will then transfer the data to the US, absorbing them in their existing data access systems, such as EarthExplorer and GloVIS, and disseminating them to their own user communities.



Washington DC, as seen by Sentinel-2A

Courtesy: ESA

Mapillary raises $8 mn Series A

Community-based photomapping platform, Mapillary, has risen $8 million in Series A funding. The round was led by Atomico, with participation from Sequoia, LDV Capital and PlayFair.

Mapillary's computer vision software automatically extracts geographic information from each photo uploaded on its platform and mobile app. It also blurs license plates and faces, and detects traffic signs. The photos are then stitched together on the map alongside other users' photos, creating a digital representation of each location through the eyes of those who have been there. Over 50 million photos have been uploaded on the platform till date, leading to mapping of more than 1.2 million kilometers in over 170 countries.


Steve Coast

OpenStreetMap founder joins what3words

The founder of OpenStreetMap, Steve Coast, has joined addressing platform what3words as Chief Evangelist. In this position, Coast is expected to strengthen existing relationships and explore new partnership opportunities for what3words in North America.

Coast, who founded the OpenStreetMap project in 2004 to encourage the growth, development and distribution of free geospatial data, is convinced that addresses are the final piece of the puzzle when it comes to realizing the promises of the advances made in mapping and navigation. "The beauty of what3words is that any mapping interface can reap the benefits," he says.

Courtesy: ISRO

PSLV lifts off with Indian navigation satellite IRNSS-1F

India places sixth navigation satellite in orbit

India is moving closer to having its own GPS-like navigation system as the country's sixth dedicated navigation satellite, the IRNSS-1F, has been successfully put into orbit by the Indian Space Research Organization. The 1,425kg satellite, a part of the Indian Regional Navigation Satellite System (IRNSS), was launched on-board the Polar Satellite Launch Vehicle (PSLV). The IRNSS aims to provide accurate position information service to users in India and the region extending up to 1,500 km from the border. India aims to put the last satellite in the IRNSS series, the IRNSS-1G, into orbit by the end of this year.

JAXA, UAESA sign cooperation arrangement

The Japan Aerospace Exploration Agency (JAXA) and the United Arab Emirates Space Agency (UAESA) have signed an arrangement "regarding cooperation in space activities and use of outer space for peaceful purposes".

This is not the first time that JAXA with be cooperating with the UAE. JAXA's microwave discharge neutralizer was onboard UAE's DubaiSat-2 satellite, which was launched in 2013. The UAESA, which was established in 2014, has been actively promoting space activities including the Mars exploration mission. With this agreement, both agencies intend to develop a mutually beneficial relationship by utilizing technologies and human resources for space exploration and utilization JAXA have accumulated for a long time. The agencies are looking to enhance the cooperation in areas like research and development, space applications, utilization of the International Space Station (ISS) "KIBO," capacity building, etc.

HERE Maps drops Windows Phone, Windows 10 support

HERE has decided to remove its branded apps from the Windows 10 store. Moreover, it will limit the development of the apps for Windows Phone 8 to critical bug fixes. The company says that the move has been taken keeping the evolving market in mind; introducing apps for new operating systems, while stopping support for others.

Currently, the HERE apps have been made compatible with Windows 10 by using a workaround that will no longer be effective after June 30, 2016. The company advises users to utilize the preinstalled Windows Maps application for maps, routes and navigation. The Windows Maps app contains many HERE elements since Microsoft has developed it using the HERE Platform and with assets they received from HERE in 2014.

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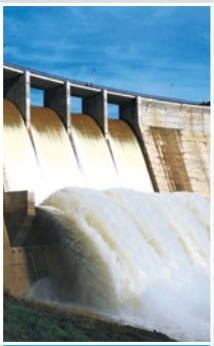
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DJI Phantom 4 knows how to avoid obstacles

Chinese drone maker DJI has released what is being touted as first self-flying drone on the market, the Phantom 4. The quadcopter comes equipped with highly advanced computer vision and sensing technology to make professional aerial imaging easier for users.

The Phantom 4's Obstacle Sensing System features two forward-facing optical sensors that scan for obstacles and automatically direct the aircraft around the impediment when possible, reducing risk of collision, while ensuring flight direction remains constant.

It also boasts of the world's best aerial-optimized 4K imaging device. With ActiveTrack, the Phantom 4 allows users running the DJI Go app on iOS and Android devices to follow and keep the camera centered on the subject as it moves simply by tapping the subject on their smartphone or tablet.

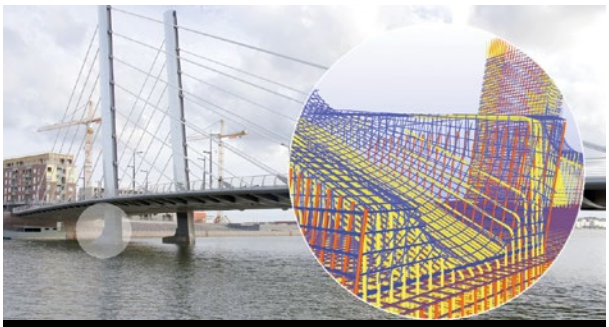
Key Features:

- Avoid obstacles automatically
- Track moving subjects automatically using ActiveTrack
- TapFly lets you fly with a tap of the finger
- Smart Return Home allows the Phantom to avoid obstacles as it returns home
- 28 minute maximum flight time, maximum control range of 3.1mi (5km)

Affordable LiDAR Sweep for drones and robots

Sensor development company, Scanse, has developed a scanning LiDAR sensor, called Sweep, to bring powerful 360-degree sensing capabilities at an affordable price. Measuring 2.5 x 2 inches and weighing 120gm, the device fits right in the palm of your hand and weighs a tad less than most smartphones today. Sweep is designed to take 500 samples per second up to a distance of 40 m. It boasts of a rotation speed of 2 to 10 Hz, which can be adjusted on the fly, so you can slow it down for more detail, or speed it up for fast reaction times.

The device uses a sensing technique which allows it to use lower power components to perform long range measurements. This lowers the cost of components, making it affordable for a larger consumer market. The company will provide an easy-to-use visualizer interface, along with many example projects to help users get started.



Trimble on software updating spree

Technology firm Trimble released new versions of several of its software in March. Here are some of the updates:

Tekla Software Solutions: Trimble has introduced three new software versions of its Building Information Modeling (BIM) and analysis & design solutions for engineering and construction – Tekla Structures 2016, Tekla Structural Designer 2016 and Tekla Tedds 2016. The solutions provide enhanced collaboration and workflow efficiency for structural steel and precast concrete designers, detailers and fabricators, concrete contractors, general contractors and structural engineers.

Trimble 4D Control: The company has updated its monitoring software, Trimble 4D Control, that supports the IBIS-FM radar device, which is manufactured by the GeoRadar division of Ingegneria Dei Sistemi (IDS). IDS has pioneered radar technologies for a variety of applications, such as, slope stability and structural monitoring in open pit mining. The addition of IBIS-FM support in Trimble 4D Control software 4.5 can trigger early warning detection of slope instability to improve safety for workers in open pit mines.

Trimble Field Link: Trimble's construction layout software, Field Link, can now be used with the R8s GNSS receiver. This addition extends Trimble's portfolio of positioning and scanning solutions that enable general contractors to take advantage of Global Navigation Satellite System (GNSS) technology when performing layout, as-built assessments and quality assurance (QA) checks, while using software designed for building construction positioning work.

BIM Scan Localizer supports Focus^{3D} laser scanner

3D scanning and measurement specialist, FARO, has announced the release of its first product under the FARO Early Adopter (EA) Program. The EA program gives users early access to new FARO products. The first product under this initiative is an add-on device for the Faro Focus^{3D} laser scanner – BIM Scan Localizer. The scan-localizer mounts under the FARO Focus^{3D} laser scanner and makes continuous 2D scans to provide detailed registration information. This eliminates the need for reference targets in overlap zones by users executing interior Building Information Modeling (BIM) scans.

While moving the FARO Focus^{3D} laser scanner from one location to another, the scan localizer tracks the laser scanner's location and the 3D scans are effortlessly stitched together to provide a complete interior building scan. This one-of-a-kind solution provides 3D scanning customers with efficiency gains of up to 2-5 times over alternative solutions for BIM as-built capture applications.

THE IMMERSIVE WORLD WE LIVE IN IS ALSO THE IMMERSIVE WORLD WE ENGINEER WITH OUR TECHNOLOGIES

Technological advancements have eliminated the need for special equipment or special crew to conduct surveying activities, believes **Greg Bentley, CEO of Bentley Systems**

Location has become all pervasive today. It is present in every aspect of our lives, including building infrastructure. How did this happen?

The 3D environment in which we live, and in which our assets are operated, has converged now to be the 3D environment in which infrastructure engineers conceive and 'conceptioneer' in the context of capturing that geospatial environment with new technologies. The operations of our infrastructure assets are roadways, railways, metros, power generation and transmission, and distribution of water systems. There are all experienced in the geospatial context, from being able to relate the reality of how infrastructure improves our lives to the 'virtuality' of how we as infrastructure engineers can improve the projects' and the assets' performance. That convergence has just come about to a degree that, I believe, is the major factor in going from geospatial to geosmart. The immersive world we live in is also the immersive world we engineer with our technologies.

The world economic recovery is uncertain once again. How do you see it affecting the business?

In the United Kingdom, infrastructure is the national

strategy. The government sees BIM as better information modeling for better project performance and better asset delivery. This is helping the engineers in the UK to become more proficient and able.

Then you have China. People say that China's bubble is bursting, but the only bubble I know of in China is in commercial properties. On the infrastructure side, the spending continues to be strong because of strong economic returns to those investments. Our users in China are doing excellent work in Utilities and urbanizing the country.

Overall, in the world at large, there is an infrastructure deficit. But, there is also a huge amount of liquidity and investment opportunity, and infrastructure is one sector which can provide reliable returns over a long term. All we need to do is creatively enable financial engineering for investment to be applied to infrastructure.

Can you share your views on this new and interesting technology called Reality Modeling, and how it applies to the infrastructure world?

It is when observations are made of the 'as operated world', captured from simple digital photography, and then processed into a reality mesh of 3D model that the engineers use in our software products to do optioneering and project delivery work. Today, unmanned aerial vehicles (UAVs) or drones are being extensively used for capturing the photos and video of infrastructure assets. Our software turns these images into 3D mesh models in the frame of reference to provide the context for the engineering work either in a new project or a retrofit, and then the same survey can be done continuously during the construction and the operation of those assets. This eliminates the need for special equipment or special crew.

You can use ordinary devices that anyone can operate. You can even use smartphones to add observations from the ground, with the software being able to process that into a geometric representation — a mesh — with photorealistic accuracy. It just reinforces the notion that geospatial technologies are not separate, but part of a geosmart convergence in the work of engineers for project delivery and asset performance.

So, what you are essentially doing is turning a non-geo thing — a photograph in this case — into a geo entity...

The mobility of information is enhanced by the location capabilities of our mobile devices. So, if you allow your smartphone to always be aware of your geospatial location, you can use it for information mobility. Your geo-tagged photographs can be used to create geosmart representations of infrastructure, such as, a water treatment plant, or transmission and distribution of overhead lines and substations, etc. For instance, a non-specialized crew working on the Nagpur metro project in India learned how to operate a drone in a week. So, the overlapping, oblique photographs which the drone took were processed through aerial triangulation in our software to yield a 3D model in the mesh format. Now, the models of the new metro would be designed by engineers in this geometric format. So, yes, a person taking ordinary photographs from a camera or drone would not be thinking that they have been using geospatial technologies.

Our software allows users to derive survey-level of accuracy, provided you give it enough number of photographs in the desired resolution. If you could achieve continuous surveying without using special hardware or without using a special crew, I would call it a breakthrough.

We heard about Bentley's involvement in the planning and execution of Pope Francis's visit to the US. Would you share some details?

The Pope came to Philadelphia, which is where our headquarters are located, in September 2015. We realized that we could apply Reality Modeling technology to create a 3D city model of Philadelphia. This wouldn't be just to visualize and show and plan — although that could be useful for the Pope's visit — but actually to provide the basis for the engineering of the temporary structures, the barricades, special facilities, the stage, and so forth, for the visit.

It had to be done in just a few weeks. That was a challenge and an experiment for us. And we like to showcase the result of the 3D city model created with a few helicopter trips in the air and some existing aerial photography that produced the basic model, all processed by the 3D Reality Modeling software. This was then provided in our MicroStation and our application environment for the engineers to actually do the work required to provide the facilities for the visit.

The outcome was very positive. We learned a lot. Our users will now benefit from that experience and how simple and quick it can be to take advantage of Reality Modeling for asset operations of the whole city of Philadelphia.

> There is a huge amount of liquidity and investment opportunity in the infrastructure sector because it can provide reliable returns over a long term

Bentley's Reality Modeling technology was applied to create a 3D city model of Philadelphia

Are others doing similar work or should we call it a technological innovation by Bentley?

Well, others are producing models from photographs. But, our particular contribution is to integrate the workflow so that the 3D result from photography is in exactly the same form factor as the engineers' own work. We are the world leaders in infrastructure engineering software. Civil engineers, structural engineers, building systems engineers, plant engineers, et al, use our software to do their designs, retrofits and construction in 3D. We have enabled them to now include the context captured from photography and continuous surveying. So, the result of the digital photography is better and pervasive engineering throughout the lifecycle of the infrastructure asset.

How can this Reality Modeling concept be applied to building smart and connected cities?

Every project to improve our cities starts with a geospatial location in which we are to design and build something. Capturing the context of that should now be a routine activity not requiring special surveying. If you have drone footage, supplemented by street-level photography, then each construction site becomes the basis, the canvas, the context, and the as-operated beginning of the optioneering for what would be the new roadway, or the new bridge, or the new substation. And those, in turn, become the digital engineering models created as a part of a smart city. These can further be connected together for a continually surveyed 3D mesh model, which can be geo-coordinated with the work the engineers do.

So, if you see something in operations and maintenance that is geo-coordinated, you can reference it to the 3D digital engineering models, and compare what was designed. For example, schematic diagrams about a water treatment plant could be connected, referenced and federated through the 3D immersive interface. A geosmart city will be navigated through a 3D interface resulting from a continuously surveyed and updated, as-operated 3D reality model captured through photography.

What is the significance of Bentley Connect edition for engineering projects?

All of our new software — including the design and analytical modeling software that is in front of the infrastructure professionals, the civil and structural and plant engineers of the world — is connected through the Microsoft Azure Cloud to everyone else. It allows resources to collaborate for sharing work, catalogues and scenarios, to improve the quality of the projects.

How does it benefit project owners?

Connection provides visibility. In the past, the owner of a project that is under construction would have been able to gain visibility into the path of construction by looking out the window and seeing what the crane is doing. But today, our software anticipates, provides and incorporates offsite fabrication of building service modules. As global sourcing becomes the way to put together infrastructure projects (for instance, a bridge can be assembled offsite and assembled and deployed on site), the path of visibility has to be a 'virtual' path of visibility. We contribute by connecting all this together through a Cloud service that can show the status of the work packaging involved.

What are some of your other offerings in asset information management?

With all the affordable sensors and inexpensive wireless devices that connect the observations from the infrastructure operations together, Industrial Internet of Things is happening very quickly. You could monitor your asset's performance with the streams of Big Data coming in, but the key question is how to make intelligent decisions from that data. How do the operators and the maintenance crew figure out when intervention is required to capitalize on economic opportunity? The digital engineering models can provide the frame of reference — the base line — to make those decisions during operations. If you know the structural model by which the bridge was created, and you have sensors telling you about the deflections and vibrations in actual practice, you can tell what should be the behaviour of the bridge. You can go from asset performance monitoring to asset performance modeling by utilizing a digital DNA created by the infrastructure engineers in the first place. All the information environments can be tied together in the Azure Cloud.

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THE FUTURE IS SMALL

Space is big. But, the satellites disrupting the earth observation market are getting smaller and smaller. **By Ishveena Singh**

When the biggest commercial satellite imagery player in the world decides to bet on something as small as the size of a shoe box, you know you are onto something. In February, DigitalGlobe announced it was joining forces with the Kingdom of Saudi Arabia to develop a constellation of highly-capable small imaging satellites. This news reinforced the belief that it's a bullish time to be in the commercial earth observation (EO) market right now.

Today, the skies are filled with eyes. Space is sprinkled with sensors. A swarm of cameras is capturing our planet's every move. And a big boom in small satellites is transforming the EO industry.

Just like your smartphones, satellites are also getting smaller and better. Nanosatellites are, in fact, about the size of a mobile. Satellites even as small as a chip, or a postage stamp, have been launched. These are called femtosatellites and weigh about 5-10 grams. But, they can do almost everything a conventional satellite does, and that too at a fraction of the cost. And though nobody is disputing that small satellites cannot replace bigger, conventional satellites on account of the sheer pixel resolution the latter offers, everybody — from government organizations and start-ups to educational institutes — is scrambling to get a piece of the smallsat pie. In 2014 alone, 158 satellites weighing between 1 and 50 kg were launched.

The space renaissance

The big bang theory of smallsats can be attributed to fast-changing technology trends cutting down gestation periods. The industry is responding to the subsequent profit vulnerability by making smaller spacecrafts quickly, deploying them even more swiftly and getting data from them rapidly.

Data needs are what fuelled DigitalGlobe's new partnership as well. Dr Kumar Navulur, the company's Senior Director of Strategic Solutions, reveals, "There are certain areas on the planet where we have really high demand from our customers. In these places, we would be complementing our smallsat capacity on top of the satellites we already have. The second aspect is monitoring. Some of our customers want more frequent visits of data. With a constellation of smallsats, we would be able to visit certain places almost 40 times a day."

Canada-based UrtheCast, which first challenged the EO industry with its innovative idea of video imagery from space, is now partnering with Surrey Satellite Technology Ltd (SSTL) to exploit the latter's expertise in providing innovative low cost small satellite solutions. UrtheCast, last year, acquired Deimos at an aggregate price of €76.4 million. According to Dr Rao Ramayanam, UrtheCast's Vice President of Sales for Middle East, Africa and South Asia, "High-revisit rates and higher data volumes have become a game-changer today. The idea is that a customer should be able to access the imagery within 20-25 minutes of a satellite passing over an area." And let's not forget that the lower costs associated with smallsats allow companies to offer our products at a rate which is less than the market price.

Less cost, more players

As satellite technology gets smaller and cheaper over the years, the barrier to entry into the space industry has also lowered. Earth observation has become accessible to corporations and start-ups alike. Organizations are now able to expand beyond their current horizons. Space businesses are popping up in every corner of the world. Small countries with limited budgets are losing their space virginity.

"It is a lot cheaper application to invest in when compared with starting a full space science program or developing geo capabilities and satellite communication. We are seeing countries such as South Korea or even Nigeria and Algeria, who started off with this technology, now have a diverse EO program," avers Adam Keith, Managing Director, Euroconsult.

Moreover, as Anne Hale Miglarese, President, PlanetiQ, points out, for each kilogram that you take off a satellite, you save tens of thousands of dollars in launching it.

And so it began...

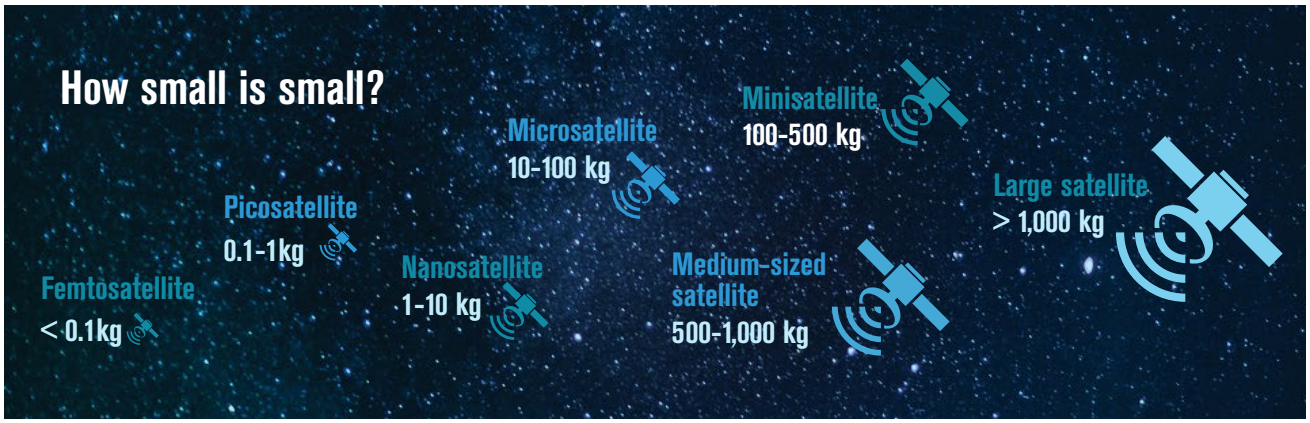
The exciting era of small satellites began only a few years ago. On November 19, 2013, Orbital Sciences launched a rocket from the Wallops Flight Facility in Virginia, US. It carried 29 satellites and released them into low-Earth orbit, a record for a single mission. 30 hours later, Kosmotras, a Russian joint-venture, carried 32 satellites into a similar orbit. Then, in January 2014, Orbital Sciences carried 33 satellites up to the International Space Station where they were cast off a month later.

The venture capital community wants to weigh the risk-reward on the amount that it costs to build these instruments.

Anne Hale Miglarese, President, PlanetiQ

The idea is that a customer should be able to access the imagery within 20-25 minutes of a satellite passing over an area.

Dr Rao Ramayanam, Vice President, UrtheCast



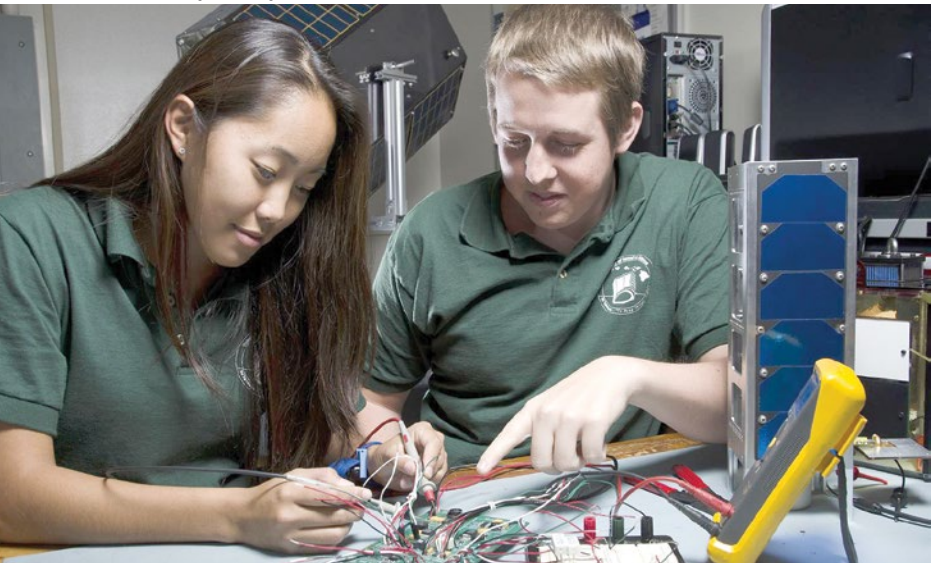
Fast-tracking innovation

Small satellites may have come into the spotlight only a little while ago, but they are already driving scientific and technological innovations. Josh Alban, Vice President (Sales), Planet Labs, asserts that these tiny metal boxes have forced the industry to move at a fundamentally faster pace. "If you are not taking 5 to 10 years just to build a satellite, you can innovate on the core technology much more quickly," he says. That enables a company to effectively serve up better and more interesting datasets to not only the existing customers, but also to people who know very little about geospatial information.

Today, partnerships are being formed to manufacture, assemble and deploy nanosatellites in space itself. Space manufacturing company, Made In Space, and low-Earth orbit services provider, NanoRacks, are collaborating to dish out a new service for cubesat developers. This service is being called Stash & Deploy. It will stash a variety of standard and customer-specific components aboard a satellite deployment platform, like the International Space Station. These components will be used for rapid manufacturing of CubeSats. Made In Space President Andrew Rush reveals Stash & Deploy would allow satellites to be manufactured quickly and to the customer's exact needs. Customers will not even have to wait for a launch vehicle. Rush believes that the entire process should take only a fraction of the time needed to build, manifest, launch and deploy satellites from the ground.

Philippe Campenon, Vice President, Sales, Blackbridge, calls attention to the fact that small satellites would also create a challenge for traditional players' capacity to anticipate the market. "This would be because a big satellite will take several years to build and deploy. During that time, two, three or four generations of nanosatellites would already be orbiting the Earth. Traditional players will need to anticipate the market correctly to ensure that the decisions they take now are relevant five to six years later."

Courtesy: University of Hawai'i



The University of Hawai'i College of Engineering students work on electronics for a small satellite

Here comes the money

Perhaps the best validation of the smallsat market is a financial one. So, it's no surprise that research firm, Markets and Markets has predicted a bullish future for the small satellite industry. The nano and microsatellite market is estimated to grow from $702.4 million in 2014 to $1887.1 million in 2019.

Start-ups like Spire and BlackSky Global have gathered tens of millions in venture cash from the likes of Bessemer Venture Partners, Lemnos Labs, RRE Ventures, and Vulcan Capital. Investments like these would have been very hard to come by just a few years ago. But these investors are convinced that in just a few years, data

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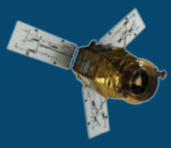
KOMPSAT-2
Launched on July 28, 2006

- 1m PAN & 4m MS
- 15km swath @ nadir
- Local time: 10:50
- Key features
  - More than 600 million archive
  - Daily collection capability of 1,700,000 km²

DubaiSat-2
Launched on November 21, 2013

- 1m PAN & 4m MS
- 12km swath @ nadir
- Local time: 10:30
- Key features
  - Consecutive imaging for 5 days



KOMPSAT-3
Launched on May 17, 2012

- 0.7m PAN & 2.8m MS
- 16km swath @ nadir
- Local time: 13:30
- Key features
  - Unique local time increases visibility
  - More information per pixel:14bits/pixel

KOMPSAT-5
Launched on August 22, 2013

- VHR X-band SAR
- Image mode
  - UH 0.85m (5km swath)
  - EH 1m (5km swath)
  - ES 2.5m (30km swath)
  - EW 5m (100km swath)
- Local time: 06:00, 18:00

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Forestry and agriculture monitoring

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from smallsats will begin impacting business models around the world.

Planet Labs is one of the early entrants in the smallsat space. It was established in 2010. And by 2015, it had gathered over $183 million in funding, and acquired almost two-decade-old Blackbridge-RapidEye constellation of satellites. Today, Planet Labs claims to have more than 400 customers. The company is chasing a long sought-after goal in the industry — to have an image of *every* spot on the globe, updated at least once every day. It believes it can achieve that goal some point between when its 100th and 200th satellite enters the orbit.

Another start-up, Skybox Imaging, raised about $91 million in venture capital for its minifridge-sized satellites. The company was acquired by tech giant Google for $500 million in 2014. After the acquisition, Google has now renamed the company to Terra Bella to drive home the point that the company will not only put small imaging satellites into orbit, it would also analyze subsequent images.

For PlanetiQ's Miglarese, the venture capital community is very detail-oriented. "They want to weigh the risk-reward on the amount of money they are willing to put forward and the amount that it costs to build these instruments," she maintains.

BlackSky founder and CEO Jason Andrews believes that the industry is transitioning from the first phase of satellite imagery, which was all about mapping, to the next wave of satellite imagery, which is all about revisit rates, activity-based intelligence and using lower cost satellites for monitoring purposes.

"The investment community sees a lot of upside opportunity in that," Andrews points out. "The global economy today is around $78 trillion. Even if we spend a small percent of that on economic and military intelligence, we are still looking at a potential market size of $100 billion for our industry. Right now, we are standing at only about $1.5 billion. There's a huge gap between where we are today and where we could be. The investors realize what a huge opportunity looking at the planet in real time could be."

Riding on earth observation

A study by Northern Sky Research has revealed that earth observation is the primary driver behind this industry's growth. This is because earth observation market suffers from data poverty in many industry verticals, like agriculture, disaster management, forestry and wildlife. The research firm believes that a staggering 40% of the nano and microsatellites, which are to be launched by the end of year 2024, will be for earth observation applications. For Euroconsult's Keith also EO is the wisest start for emerging players in this industrial process with the potential of developing more extensive programs later on.

Fabrizio Pirondini, CEO, Deimos Imaging, agrees. "The business of EO imagery is very much government driven. But, now, we are seeing a new B2C business developing on the top of this, and that is fuelled by nanosatellites," he insists.

The EO industry is witnessing trends like better resolution, improved accuracy, faster access to imagery and larger volumes of data to handle. Resolution is an important criterion, but it's not the only one anymore. Equally important is the freshness of the data that the companies bring to their customers.

Out with the old, in with the new

The swift pace of the small satellite revolution is making companies rethink their business models as well. While Andrews believes that the strength of nanosatellites lies in

The investment community sees a lot of upside opportunity in small satellites.

Jason Andrews, Founder and CEO, BlackSky

It is a lot cheaper application to invest in when compared with starting a full space science program or developing geo capabilities and satellite communication.

Adam Keith, Managing Director, Euroconsult

Spire's weather satellite prototype is about the size of a bottle of wine. Courtesy: Spire

With the proliferation of new sensors in space, we are in the midst of a sensor revolution. This would lead to changing business models.
Robbie Schingler, President, Planet Labs

Traditional players will need to anticipate the market correctly to ensure that the decisions they take now are relevant five to six years later.
Philippe Campenon, Vice President, Blackbridge

their ability to track things that drive commerce around the planet (cars, trucks, trains), Planet Labs President Robbie Schingler is of the view that in the future, people will subscribe to information feeds rather than pixels.

"With the proliferation of new sensors in space, we are in the midst of a sensor revolution. This would lead to changing business models," insists Schingler. "It makes more sense for a company today to keep the vast amount of data it collects with itself, and then write their applications through a Web-based API. In the near future, value added service providers will come up with very interesting algorithms and information feeds."

Andrews maintains that BlackSky will not be stepping up the resolution game anytime soon. "Right now, the resolution of our satellites is 1 meter. Our business is to enable people to look at the global economy, and 1 meter is the critical resolution required to do that. We have no intention of going for big satellites with 30-cm resolution. We believe it's all about revisit rates and persistence; so we will stay optimized around that solution space," he says.

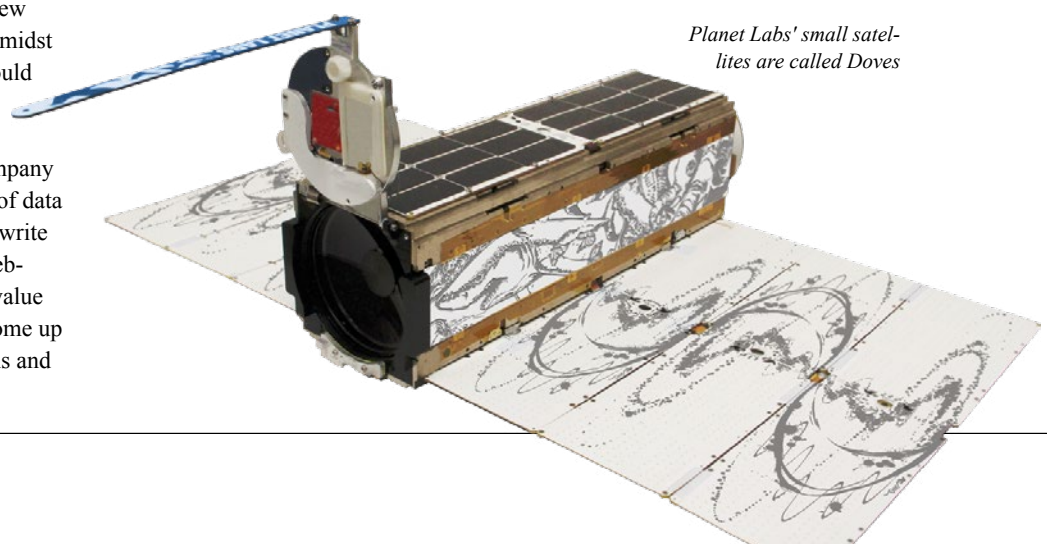
Up, up and away

However, the key question remains — how do we get these satellites into orbit? On June 28, 2015, a SpaceX Falcon 9 rocket exploded minutes after it took off from Cape Canaveral in Florida. Planet Labs lost all eight of its satellites aboard. In fact, by mid-2015, analysts had expected around 100 smallsats to be launched. Only 50 made it to space. The launch industry has to understand that if it can't begin launching more frequently, and more reliably, smallsat assets will remain trapped on earth. Also, when small satellites have to "piggy back" onto heavy-lift rockets whose primary mission is to bring a bigger payload to a specific orbit, it becomes difficult for them to easily get where they need to go.

This is where New Zealand-based Rocket Lab comes in. The space-flight operator, which plans to begin commercial operations this year, is currently taking online bookings for CubeSats. You can select a date, a destination and even your satellite's position on the rocket, just as you would do while booking an airline ticket for yourself. Launch fees start from as little as $50,000. Rocket Lab CEO Peter Beck has even said that if the company has trouble filling seats close to the time of the launch, they will dish out discounts to make sure that the flight is full.

Spire CEO Peter Platzer is so upbeat about having a launch provider that would cater to his precise needs that he has signed an agreement to use Rocket Lab facilities for 12 launches over the next 18 months. "It's the difference between relying on your neighbors to alert the police if someone breaks into your home when you are away, and having a silent alarm linked directly to the police," he says.

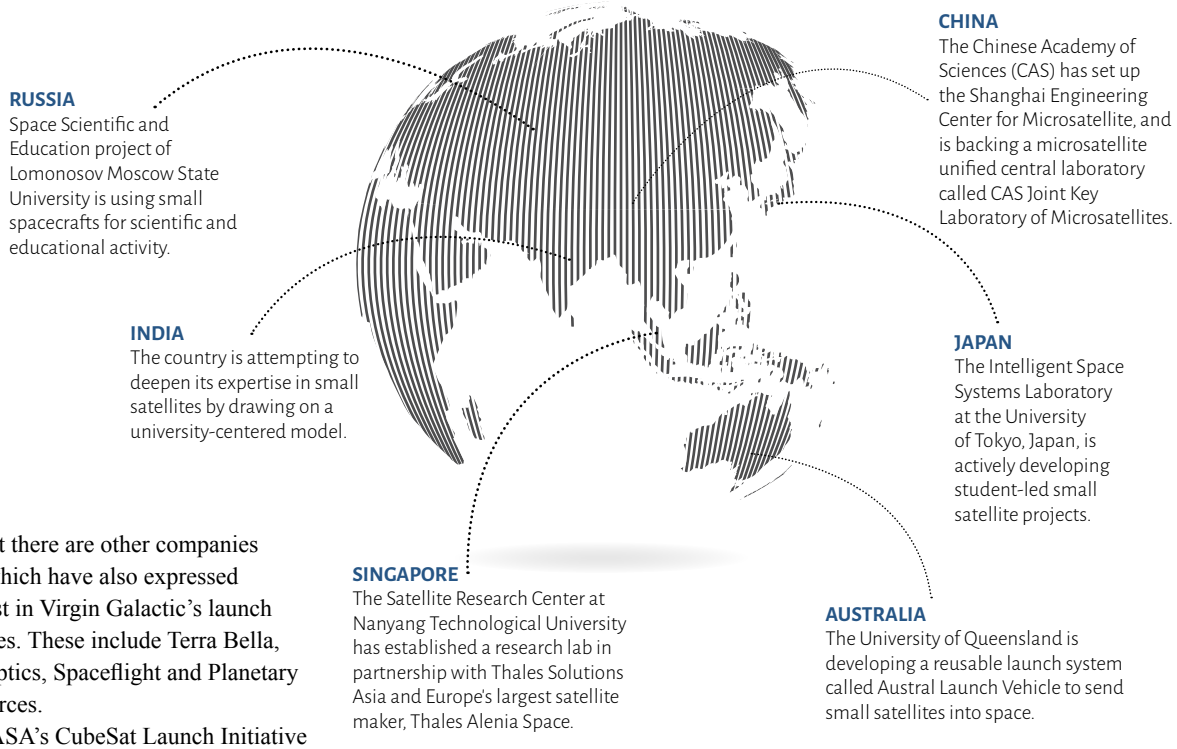
Business tycoon Richard Branson is convinced small is the new big. His company Virgin Galactic has bagged a contract to place around 648 micro-satellites into orbit over 39 launches. These tiny sats will be carried into space by a two-stage rocket called LauncherOne. The microsats that the rocket will debut with have been commissioned by OneWeb, which aims to build the world's largest satellite network for global Internet access.



Planet Labs' small satellites are called Doves

Asia bets big on small sats

Even though a majority of Asian players are new to the space game, they come armed with big ambitions centered on small satellites.



But there are other companies also which have also expressed interest in Virgin Galactic's launch services. These include Terra Bella, GeoOptics, Spaceflight and Planetary Resources.

NASA's CubeSat Launch Initiative has also come to the industry's rescue. The initiative allows small satellite payloads to fly on NASA rockets planned for upcoming launches. NASA has selected 105 CubeSats from 30 US states till date. Out of these, 37 have already been launched, and 16 more are scheduled to go into space by the mid of 2016.

What about the junk?

As space gets sprinkled with teensy satellites, the population of debris or "space junk" is also increasing. NASA estimates there are more than 20,000 pieces of debris larger than a softball orbiting the Earth. They travel at speeds up to 17,500 mph, fast enough for a relatively small piece of orbital debris to damage a satellite or a spacecraft. There are 500,000 pieces of debris the size of a marble or larger. There are many millions of pieces of debris that are so small they can't be tracked. And small satellites go into the low-earth orbit that has the greatest amount of debris already.

Gen. John E. Hyten, Commander of the US Air Force Space Command, stresses on the need for international norms to deal with space debris. "If you create mess in space, that mess is going to be there for generations to come. Right now, there are very few norms established for how you operate in space. We need to figure out how to at least get some stuff out of the geo-synchronous belt — which is our most valuable real estate — to have a more pristine geo environment," he says.

Hyten also emphasizes how responsible space behavior needs a new definition. "It doesn't matter whether you are a commercial company operating 400 satellites or just one satellite, you have to be responsible and not create debris. You need to be transparent with the way you operate."

As technological advancements, cheaper components and frequent, inexpensive launches make hurling spacecrafts into orbit easier than ever, it's safe to say that small satellites will play a big role in the future. A boost in the daily imagery refresh rate will lead to newer applications in sectors like military, environment and agriculture. The marriage of small satellites with big data analytics is going to open up new avenues in the emerging space order. The world, as we know it, is going to change. And, right now, we cannot even fully anticipate how.

Ishveena Singh,
Senior Assistant Editor
ishveena@geospatialmedia.net

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NEXT STOP: HOLLYWOOD!

Conventional wisdom says only big satellites can answer important needs; small satellites are changing that view.

By Robert Zitz

If you watch enough spy movies you will see a large satellite whiz by and on command, point its massive camera at a street scene hundreds of miles below. Zooming in on the people and items of interest, the audience sees the satellite monitoring events in real-time to help stop a villain before it is too late. Hollywood may be overstating capabilities, but one part they get right is the sheer size of some current and past government satellites. For instance, NASA's Hubble Space Telescope is 43.5 feet long — the size of a large school bus — and weighs 24,500 lbs; and the National Reconnaissance Office's recently declassified 'Hexagon' imaging satellite was 30,000 lbs. and 60 feet long.

Highly capable earth observation satellites had to be big, heavy, complex, and take a long time to plan, design and construct. They required highly specialized manufacturing. These factors made large satellites expensive to build, expensive to launch, and only a few were affordable at any given time. Conventional wisdom says only big satellites can answer important needs. Small satellites may be changing that view. Over the last few years, a new generation of space entrepreneurs raised nearly a billion dollars from private investors and launched more than 100 small satellites. Top space industry prognosticators forecast over 500 small satellites in orbit by 2020; there are over 1,000 in various stages of planning or development today.

So what constitutes 'small'?

Unlike schoolbus-sized satellites, small satellites are a class of space-

craft weighing between 2.2 lbs. and 1,100 lbs. That is like going from the size of a wine bottle up to the size of a Meneghini La Cambusa refrigerator. Small satellites were once mainly science projects for undergraduate aeronautical engineering students, but top professors and young engineers recognized that advances in consumer electronics could revolutionize the field. They capitalized on the commercial sector's miniaturization of sensors and other components, exponential increases in computer processing, better communications devices, advances in materials, the rise of common interfaces and the streamlining of manufacturing processes in high tech industries. They invented the simple yet innovative structural design now known as a 'CubeSat' — a 10x10 cm unit (1U) which enables scaling of different size satellites using a simple building block approach (2U, 3U, 6U, etc.)

The improved technologies, designs and processes led to smaller but still capable systems at lower costs. For example, a Planet Labs constellation (a 'flock') of nearly 100 wine bottle-sized satellites (8.8 pound 'doves' – thousands times lighter than traditional imagers) is currently collecting three to five meter resolution imagery worldwide. That is good enough to answer many commercial and civilian applications, such as natural resource exploration and monitoring, crop and vegetation analysis and disaster support.

Large numbers of satellites offers the ability to rapidly revisit spots on the Earth. Frequent imaging aids business and government analysts charged with monitoring commerce, treaty and regulatory compliance, food and water supplies, deforestation, and other issues. Rapid revisit is also of keen interest to military and intelligence analysts who are willing to trade resolution to gain 'persistence'. The idea is to detect important changes in time to make a difference. Small satellites offer a means to gain persistence at affordable costs. Small satellites may offer the potential to supplement traditional national space assets in crises; senior decision makers discussing the need for space resiliency are considering how small satellites may be part of the solution.

Small satellites may offer the potential to supplement traditional national space assets in crises; senior decision makers discussing the need for space resiliency are considering how small satellites may be part of the solution

Players in the market

Numerous small satellite companies are pursuing the market. In addition to Planet Labs, Google's Skybox Imaging (recently renamed as Terra Bella) is flying SkySat 1 and SkySat 2 with plans for a 24 satellites constellation. Each dorm room refrigerator-sized SkySat satellite can collect sub-meter resolution imagery and high definition, 90-seconds video clips. At that quality, a wide array of customers' specific questions can be answered with the added benefit of monitoring movement of objects. BlackSky Global's plan calls for 60 satellites collecting rapid revisits at sub-meter imagery; Urthecast's plans include 16 satellites flying in pairs collecting sub-meter visible imagery on one satellite with L and X band radars on the companion satellite. Many other companies are entering into the small satellite market and as a result, more than 20 companies are working to develop low cost, rapid launch capabilities specifically for smaller satellites.

Harvard Business School Professor of Marketing Ted Levitt famously said, "People don't want to buy a quarter-inch drill, they want a quarter-inch hole!" The new generation of space companies do not see themselves as in the satellite business. They think of their business as an information service: the delivery of answers for customers' hardest problems. Rather than focusing just on space hardware, small satellite companies use the Internet, Cloud computing and advanced analytics software to provide an intuitive user interface. They plan to do Big Data analysis for their customers. They will ingest, correlate and geo-rectify their pixels with multiple other sources of information; they intend to run change detection algorithms to detect anomalous events to tip analysts and other collection systems. These new firms are even building the flexibility for customers to do their own shopping for images and drive new collection if desired. Traditional Big Data companies are taking note of the smallsat firms.

Interest in small satellites is growing sharply. The United States Geospatial Intelligence Foundation (USGIF) held the first Small Satellite Workshop at National Geospatial-Intelligence Agency (NGA) headquarters on November 16 and 17 last year. Seniors from the White House, Congress, military services, intelligence agencies, industry and academia gathered to discuss needs and technical capabilities. They began to shape a common understanding of small satellites. No, not science projects anymore. Next stop: Hollywood.

Robert Zitz,
Senior Vice President, Leidos

Dr Kumar Navulur, Senior Director of Strategic Solutions

Taner Kodanaz, Director Leadership

SMALLSAT FORAY WILL ADD TO DG'S HIGH-RES IMAGERY ARSENAL

DigitalGlobe has finally forayed into the small satellite segment in February as it joined hands with TAQNIA and King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia. This is a significant move from the world's biggest private satellite player which has been facing the prospect of new competition from companies using less expensive small-satellite technology. We caught up with two senior DigitalGlobe executives — **Dr Kumar Navulur, Senior Director of Strategic Solutions**, and **Taner Kodanaz, Director Leadership**, to speak on the issue...

What prompted this decision? Was it in the works for a long time?

Kumar Navulur: It is not about small or big satellites; it is more about the data needs of our customers. There are certain areas on this planet where we have really high demand. This is where we started complementing the small sat capacity on top of the satellites we already have. The second aspect is monitoring. Some of our customers want more frequent visits of data. Today, our high satellites come in once a day at 10:30 am. Now, with these small satellite constellations, in some places we can come back almost 40 times a day, along with our high satellites. So, it is a combination of what the customer wants, which includes capacity as well as monitoring in those areas.

From the strategy perspective, DigitalGlobe has been thinking about this for a while. We want to leverage our high-quality imagery and process it with smallsat data so that it becomes more accurate.

Taner Kodanaz: We believe that small satellite imagery is of limited value. What is unique in this deal is the combination of our high-resolution and accuracy imagery that only DigitalGlobe can offer because of the satellites we own.

In addition, we have excellent ground infrastructure and can operate on a large scale, which gives us the ability to perform coordinated task. Therefore, we will be able to address not only shortfall of the standalone small satellites industry but will also be able marry high-resolution capabilities with low-resolution capabilities to provide much accurate high-resolution content in the end. It is a unique combination.

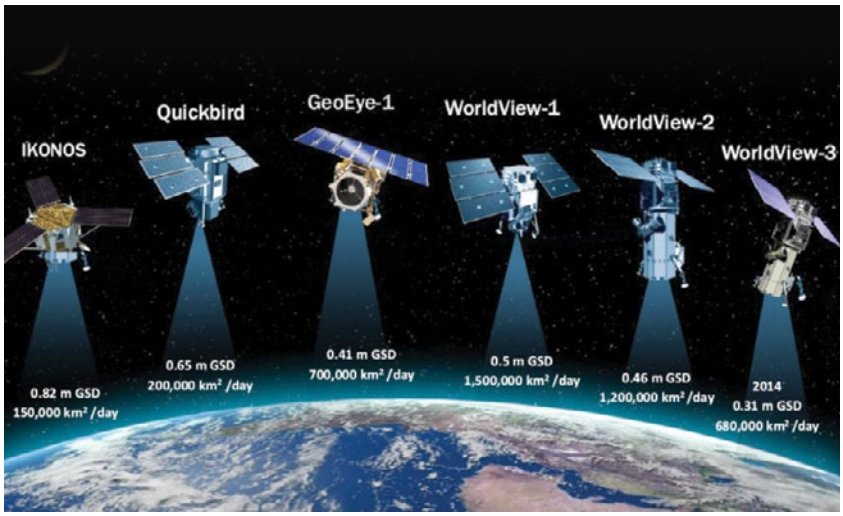
What is the investment and revenue-sharing model in this joint venture?

TK: TAQNIA and KACST are responsible for investments in the space segment — building and launching of the satellites. DigitalGlobe will be responsible for ground infrastructure. TAQNIA will task and monetize 50% of the constellation capacity inside the KACST communication zone and it will earn a revenue share of monetization of all the capacity generated by DigitalGlobe. We will task and monetize 100% the constellation capacity outside the Kingdom.

How would you be positioning this unique capability of DigitalGlobe in expanding the small satellite industry?

TK: This disruptive model will extend our position and enhance our ability to innovate. We believe that this is a validation of our leadership position in the technological and global industry space. So the model of this partnership

> This disruptive model will extend our global leadership position and enhance our ability to innovate



With WorldView-4 joining WorldView-3 in the DigitalGlobe constellation later this year, the total constellation will have the capability to image a location an average of 4.5 times/day at 1m GSD or less

confirms the value of our infrastructure and our proven tested value around security, scalability and others. So far it is the model that will lead the industry.

KN: From our perspective, small satellites are of limited use by themselves. In the end, we talk about pixel resolution. We launched 80-cm resolution in 1999. We have already launched 30-cm resolution. We have regulations from the US to capture 25-cm details. We are focusing on capturing finer details. But most of the smallsats are at sub meter resolution of 80 cm — very comparable to DigitalGlobe's Ikonos satellite. Smallsats are complementary and allow us to fill capacity gaps as well as provide monitoring for our customers if they are interested to visit a given location more times a day.

> We want to leverage our high-quality imagery and process it with small sat data

Should this be seen as an important signal for the EO industry that small and nanosats are here to stay and also play a huge role?

KN: It is not about the technology; it is about the content you are creating from these satellites. The one thing I am encouraged about is if you look at the option of geospatial imagery, since Google Earth came along in 2005, we estimate that there are over 2 billion users using the imagery today. So, that number is going to grow substantially as the number of smartphones goes up. With more usage will come more demand. From that perspective, the more satellites we have, the better to provide this information.

Will DG continue with its R&D and investments in the big sat area? Or are we going to see a change in strategy for future satellites from DigitalGlobe?

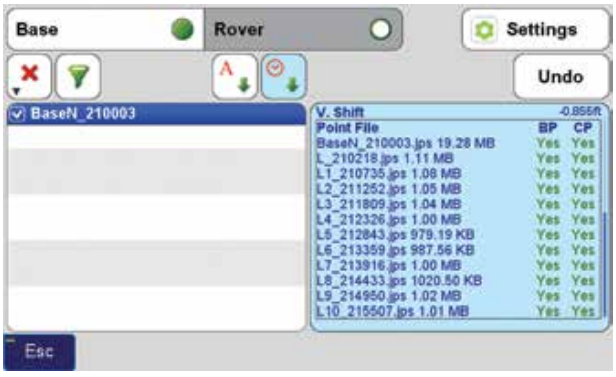
KN: Big satellites are at the core of what we do — high-fidelity, high-accuracy and high-finer detail imagery. We would be leveraging not only smallsats; we have been doing third-party imagery for a long time. So, our focus is on solving a customer's problem by providing content from multiple sources. We believe that our high-quality imagery becomes the foundation to make them more accurate.

TK: We already have an existing vision for our next-generation constellation and this is in line with that strategy. I don't think that this will be changing all that. In fact, this is all very much part of the strategy that we already have for our future. DigitalGlobe will optimize orbits in tasking new constellation with rest of its constellation to deliver superior performance. The small satellite constellation will give us capability and opportunity to optimize our existing assets, so that we can meet our customer's demands.

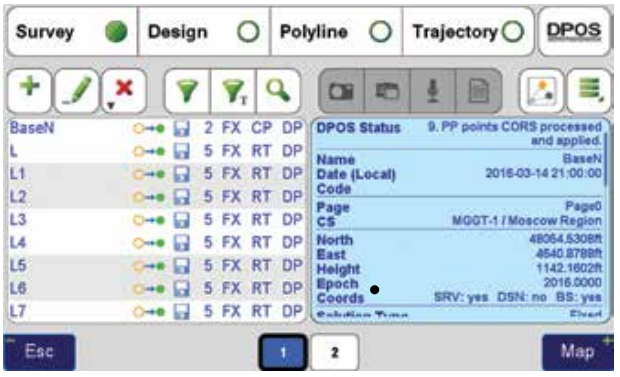
Is the imagery market heading in the direction of commoditization?

KN: The number of consumers is growing exponentially. So, there will always be that aspect of commodititization because more satellites are coming in. So, if you look at the very high-resolution market, we are the only ones providing 30-cm resolution satellite imagery providers. And then when you look at the newcomers, the advantage we have over them is because we have a two to five year headstart, we have built a rich archive of 30-cm images across the globe. Therefore, it is always a game of catch-up for the newcomers. So, commoditization for us is — yes, we have more competition, but we have a lot more users coming up. But, you will see us investing more in providing solutions to the data market in the form of platforms and Cloud capabilities.

Post-process and CORS process missed points... Automatically!



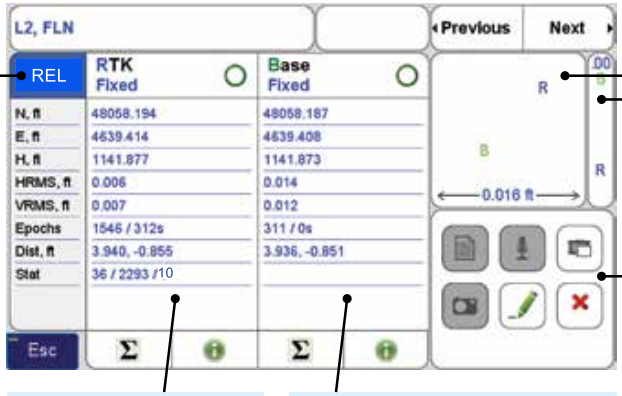
Status of DPOS and Hybrid RTK processing for this session.



Status of each point and indication that base was DPOSed and corrections were applied.

Switch between REL (Relative) and ABS (Absolute) screens.

RTK and post-processed rover solutions based on autonomous (standalone) position of the base (Relative).



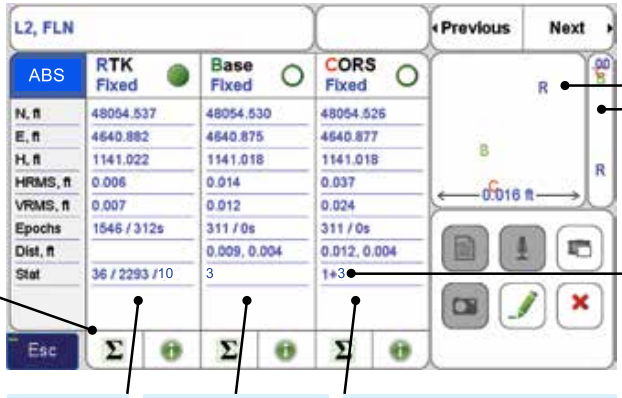
Horizontal and vertical graph of Relative solutions.

Access notes, audio, photos and screen shots that are attached to this point.

RTK solution (relative to autonomous position of the base).

Post-processed solution (relative to the autonomous position of the base).

Three types of Absolute rover solutions after autonomous position of the base is corrected with CORS data.



Horizontal and vertical graph of Absolute solutions.

Statistical details.

Number of CORS stations used.

Corrected RTK solution.

Corrected post-processed solution.

Solution post-processed directly with base and with CORS data.

Your thick trees and Our six RTK engines...

"This thing is bad ass!"

"I used "Beast Mode" on a small project yesterday and all I can say is WOW!!!! Did Javad and Red Bull team up to enhance RTK or did my system drink hypercaffeinated coffee when I wasn't looking? Amazing accomplishment/development Javad. I can't imagine using any other GPS equipment."

"the data collection will make your whole body stiff, and quiver from head to toe. It is flat awesome."

"We are considering a third system (these things are awesome)"

"got some shots that he could not get with our gr5's"

"Btw, pardon my French, but holy shit. I got some ridiculous 'fixes' today in some horrible situations. Reset receiver, moved around, etc. Tried to get a bad fix but had a hard time doing it."

"The LS has increased our productivity 2:1."

"On a side bar, the highway contractor had a guy using a Trimble for his as-built shots. My Javad ate his lunch on fixes and the verify routines. He had never seen anything like it. His was stop, drop, and go."

"I've been using BEAST MODE RTK and it works very fine even in heavy canopy. Tremendous application."

"The only bitching now is for the crew that has to take out the Hyper V."

"I often get 2 days of work done, in a day."

"This thing is bad ass!"

JAVAD ...making friends!

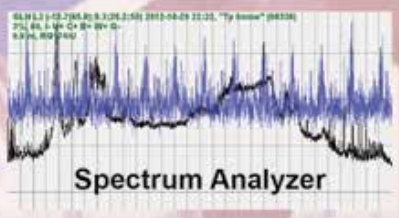
HOW DEEP IS YOUR LOVE

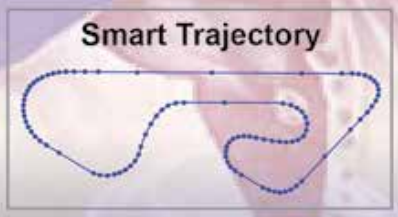
for science?
for technology?
for survey?
for money?

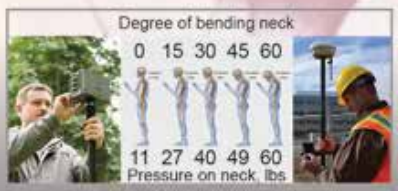
and for

Hybrid RTK
Automatic

and much more...

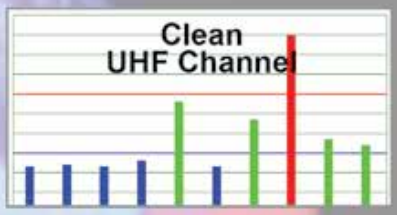


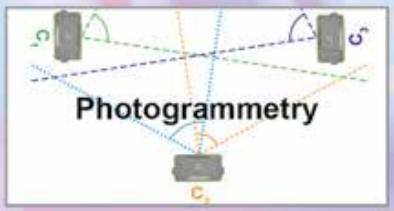




BEAST MODE RTK
Real 5-Hz Base Station Transmission

RAMS
Remote Assistance & Monitoring Services





REVERSE
SHIFT<<it

>>>
Wolfman Jack

JAVAD
www.javad.com

Hybrid RTK

Triple-Check your RTK results and ...

It triple checks the accuracy of RTK solutions by post-processing and CORS processing. In addition, if RTK can't a get fix (because of bad environment or bad communication with Base) Hybrid RTK comes to your rescue... automatically.

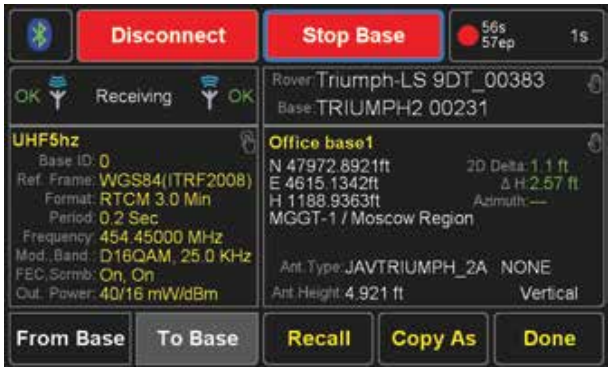
Nine Automatic Steps of Hybrid RTK

Confidence and Speed... Unlimited!

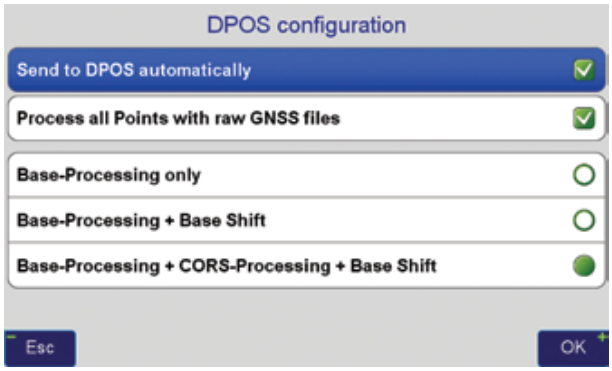
You do this

1 Downloading base data.

When your RTK job is finished, go to your base and in Base/Rover screen click "Stop Base". Base data will be downloaded to TRIUMPH-LS via fast Bluetooth automatically. All of the following steps will be performed automatically too when WiFi/Internet connection is established.



DPOS options



Automated steps

2 Base data downloaded.

3 Awaiting DPOS server connection.

4 Rover points and base data sent to DPOS. Awaiting DPOS to process base-rover.

5 Rover points processed with base (relative).

6 Base data sent to DPOS to be processed with CORS data. Awaiting CORS data.

7 Base processed with CORS and corrections applied. (Absolute)

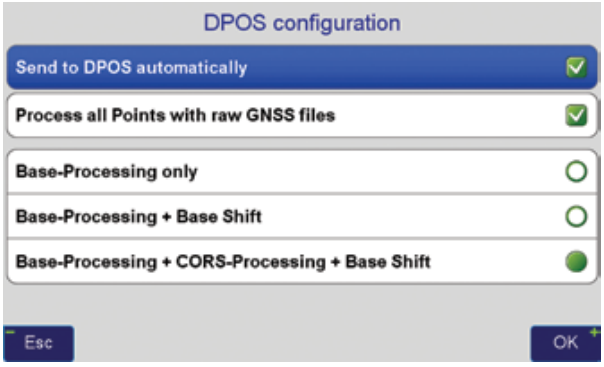
8 Base and rover points sent for CORS processing.

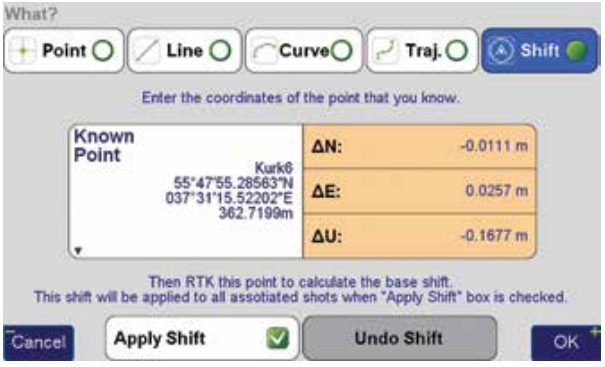
9 Rover points individually processed with CORS data.

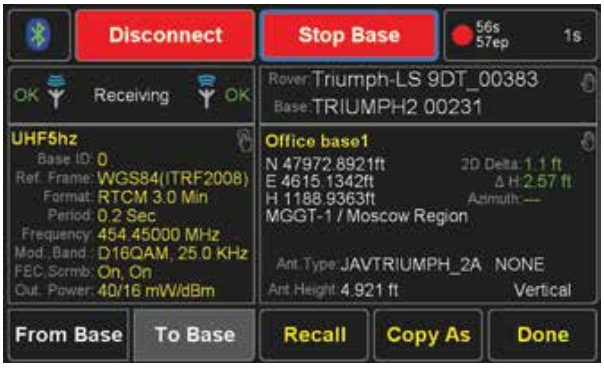
4 DPOS-it, Reverse-Shift-it, CORS Process it, AUTOMATICALLY. See Hybrid RTK too.

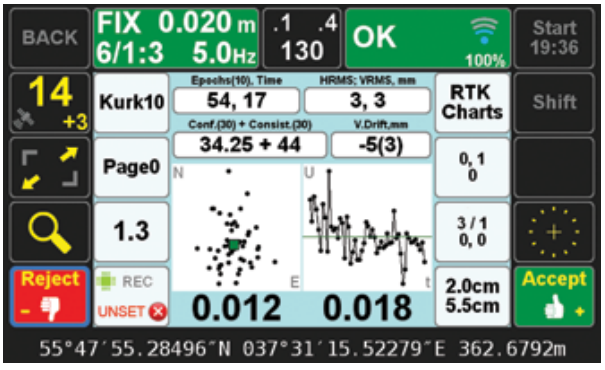
DPOS-it:
Press Stop Base and this will automatically **download** the raw GNSS base data to TRIUMPH-LS and send it to **DPOS** for processing with data from nearby CORS receivers. The TRIUMPH-LS then receives the **correct coordinates** of the base and **shifts** all the rover points accordingly. It can also process your rover points directly with CORS stations too. You can triple check your RTK results.

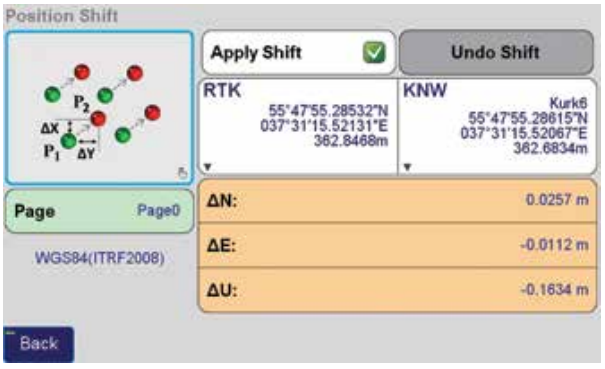
Reverse-Shift-it:
1) Take the TRIUMPH-LS to a **known point** and select the "**Shift**" function in the Setup Advanced screen. 2) Enter the **known coordinates** of that point. 3) Take a **shot** at that point and a base station shift will be **calculated and applied** to all previous and subsequent points surveyed in this session. You can then also use the newly surveyed points as known point for leap frogging during the project.





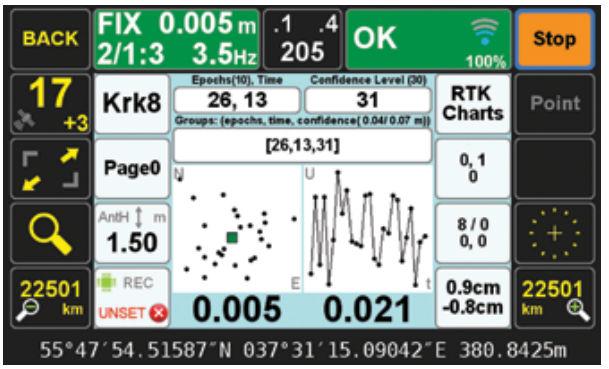




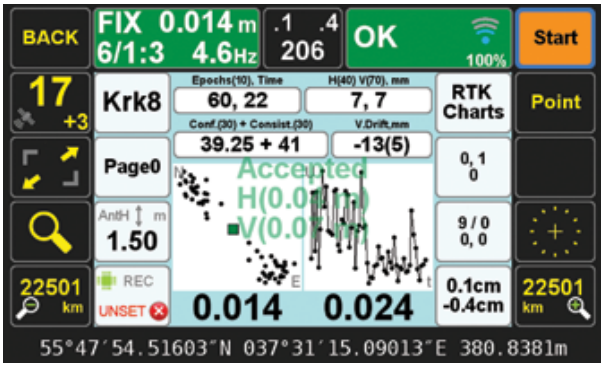


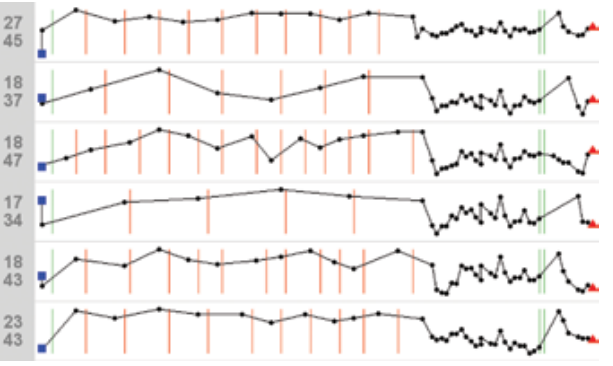
3 RTK Survey

Use your rover to perform your tasks. We have combined UHF and Spread Spectrum Frequency Hopping (FHSS) in the same module in TRIUMPH-LS as an option. The automatic "**Verify**" feature (Phase-1 and Phase-2) ensures that you will never get a wrong solution.



Since your RTK baselines are short, you benefit from all advantages that we discussed earlier BUT all your rover shots are shifted by the offset error of the autonomous base coordinates (up to several meters). "DPOS-It" or "Reverse-Shift-It" to correct for the error from the autonomous position.





1 Equip your car

Mount the TRIUMPH-2 and radio on top of your car or truck. You can use either **UHF or FHSS** (Frequency Hopping Spread Spectrum) radios. You may want to bolt them down in your car for everyday use. FHSS does not need a license but its range is limited to a couple of miles. UHF has a longer range (up to 50 miles with a 35 Watt amplifier) but it needs a license. FHSS is particularly helpful in connection with our Beast Mode RTK which provides corrections from a TRIUMPH-2 near your job site. Use an appropriate long whip UHF/FHSS for longer range transmission.

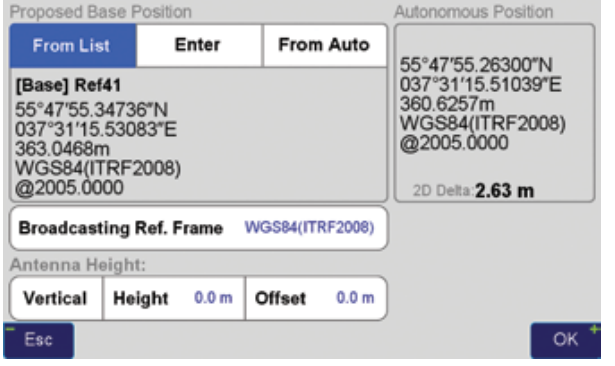
HPT401BT
1W UHF Radio

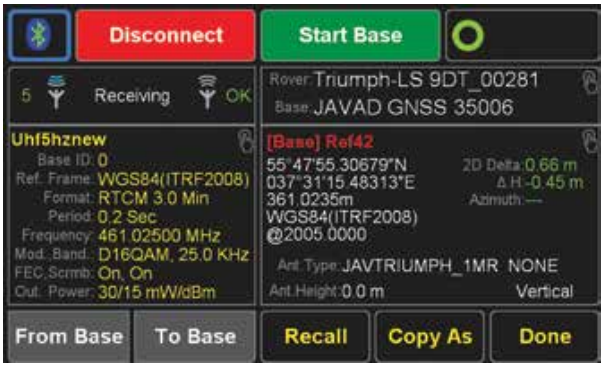
TRIUMPH-2
GPS+GLONASS
L1/L2

2 Park your car, Start Base

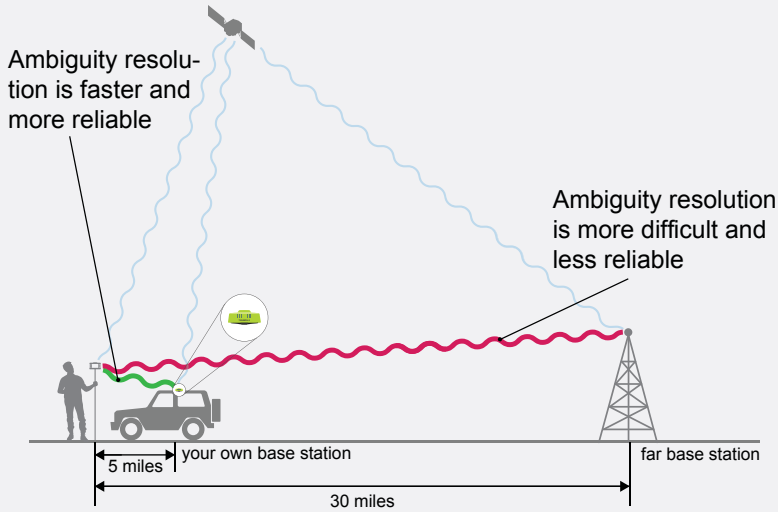
Park your car in an open area near your job site. It may be even in the middle of your site job. Engage all the brakes and ensure the car will not move. The Base/Rover Setup screen makes it easy to configure the base and rover with the same parameters.

Use "**Auto**" for the base coordinate. "Auto" will use an autonomous solution as the base coordinates which may be off by several meters (this will be corrected later). Then click **Start Base**.





Advantages of your own base station and short baselines



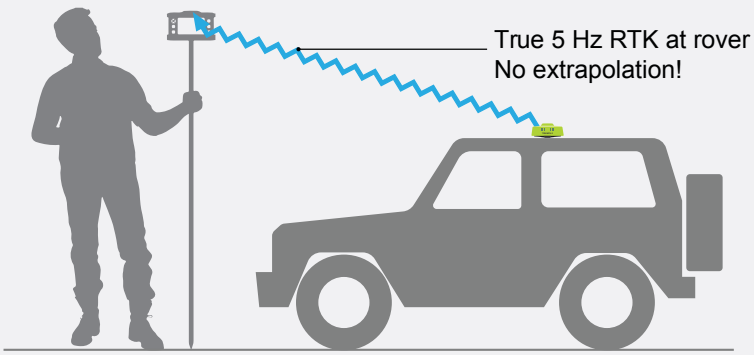
1. Shorter baselines provide significantly better **reliability** because the ambiguities are much easier to resolve and the correct ambiguity solution has an obvious contrast.

2. Shorter baseline has better **accuracy** because most of errors (like atmospheric and tropospheric effects) are common and cancel.

3. Shorter baseline ambiguities are resolved much **faster**. In longer baselines, incorrect ambiguities may pose as being correct in the statistical evaluations and it takes longer to isolate incorrect ambiguities.

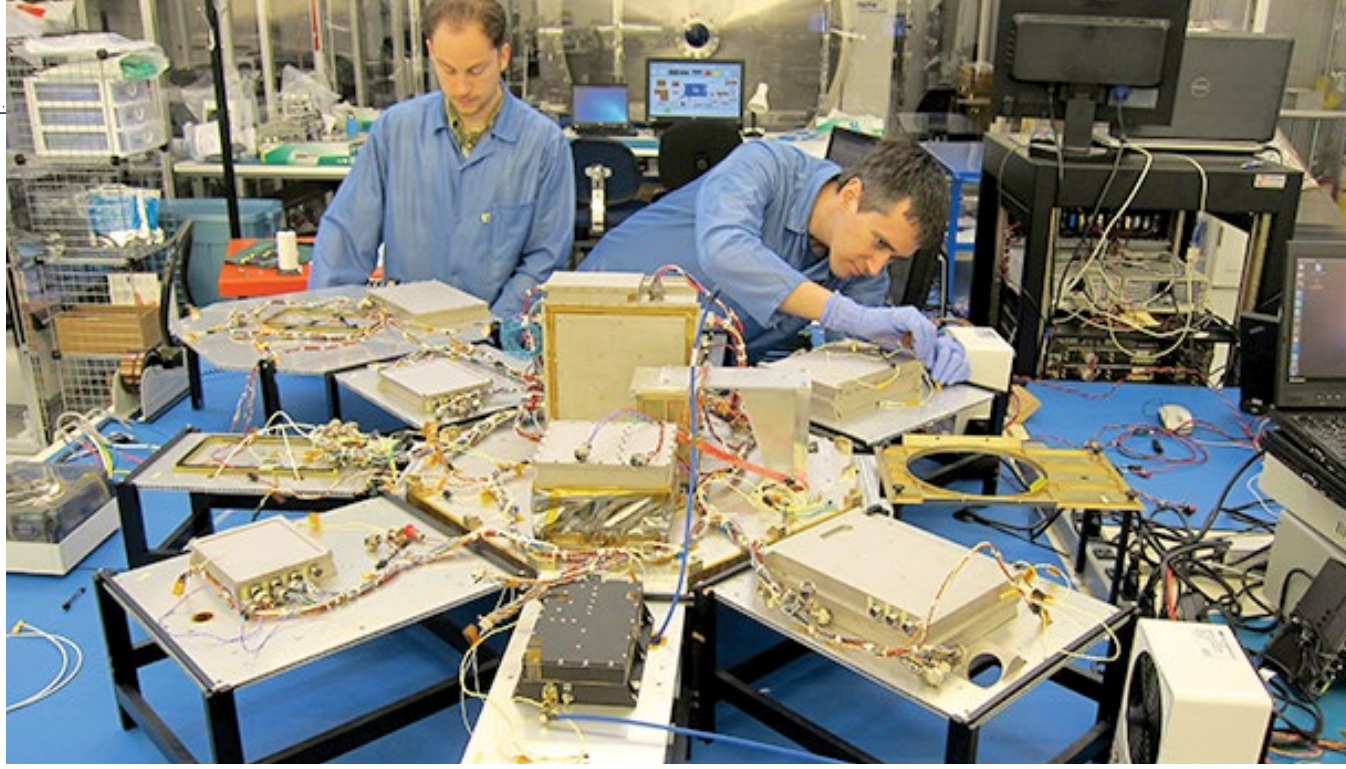
4. Shorter baselines make it feasible to work in **difficult** areas (under tree canopy and in urban environments) because ambiguities have better contrast and are easier to resolve.

5. **Beast Mode RTK** is available only via our TRIUMPH-2 and TRIUMPH-1M base station. It makes ambiguity resolution up to 5 times faster because base station transmits base data 5 times per second. 5-Hz Beast Mode RTK is totally different from the up to 100-Hz RTK that is done by extrapolating the same 1-Hz data 100 times per second AFTER the ambiguities are fixed. This extrapolation technique does not improve the ambiguity resolution speed and is mainly used in applications like machine control after the ambiguities are fixed.



6. In addition to savings due to speed and reliability, it saves you RTN and communication charges. A complete system, Base + Rover + Radio + Controller & Controller Software, starts at **$19,990**. 0% financing available ($1,537.69 per month for 13 months) to active license US Professional Land Surveyors (PLS). Extended finance terms also available

contact **sales@javad.com** for details.



Big Smaller Satellites PERFORMANCE

Canada-based Space Flight Laboratory provides end-to-end space missions for govts on tight budgets by building big satellite performance into smaller satellites.

By Dr Robert E. Zee

The Space Flight Laboratory (SFL) develops complete space missions for international customers with high performance demands but tight budgets and short schedules. For over 17 years, SFL has been pushing the performance envelope by building big satellite performance into smaller satellites. By doing this, SFL intends to not simply be disruptive, but to continually set the high bar of what is achievable in smaller packages and lower than expected cost.

SFL develops missions for all applications — earth observation, monitoring and remote sensing, asset tracking, communications, science, and technology demonstration. SFL's goal is to make it easier for the entrepreneur to start a new business in data services without the need to take on the sometimes underestimated risk of satellite manufacturing or the constant demand for technology refresh. SFL helps companies, governments, and other institutions achieve their space data objectives by providing professionally built, high-quality satellites so that they can focus on their business rather than on the engineering and continual improvement of satellites. This allows the world to harness regular advances made by SFL while resting assured that the technology is of high quality and reliability. SFL's capabilities are complete end-to-end services, from initial mission conception, to satellite integration and test, to arranging launches on a regular basis, to commissioning and operating satellites. These satellites can be replicated by

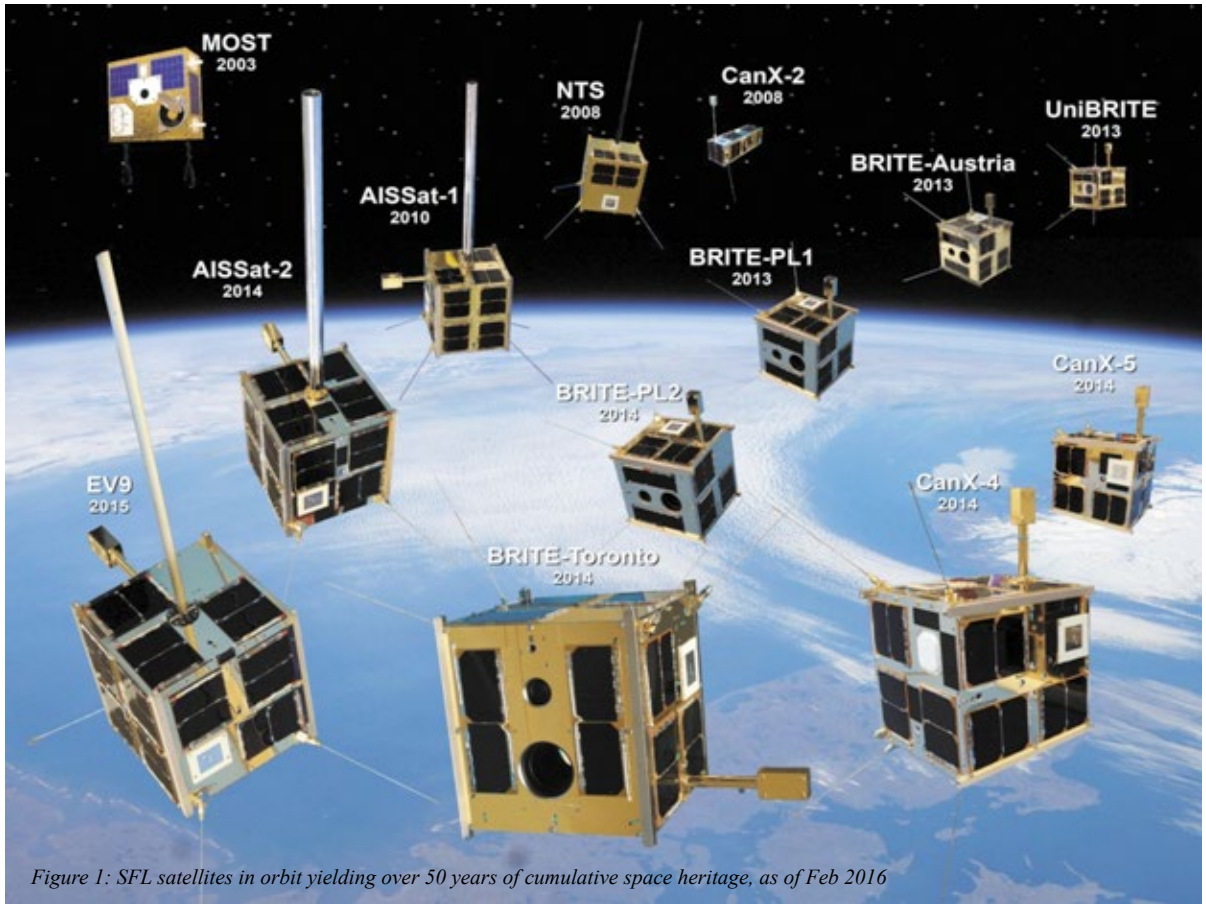


Figure 1: SFL satellites in orbit yielding over 50 years of cumulative space heritage, as of Feb 2016

SFL or through the customer's mass production facilities if so desired, for large constellation projects where it is desirable to bring production in house.

Figure 1 illustrates some of the satellites that SFL has launched and operated in orbit. These satellites are surprisingly small for their high performance capabilities. The cumulative on-orbit heritage from these satellites exceeds 50 years. Each satellite has broken barriers of performance and exceeded the state-of-the-art at time of launch.

At only 53 kg, the "most" micro satellite was Canada's first space telescope, and the world's first microsatellite with high precision attitude control, taking microsatellites from simple "toy" missions to an entirely new regime of serious applications. Another paradigm shift occurred when CanX-2, as one of the first cubesats in orbit, was, to SFL's knowledge, the first 3.5-kg satellite to demonstrate three-axis attitude stabilization, propulsion, and a high speed S-band downlink with a 1 Mbps data rate (note at the time, others were stuck with kilobits per second). NTS was another revolutionary satellite, demonstrating responsive space capabilities before the catch phrase came into being, having been developed in only six months and launched in the seventh, and providing time-critical commercial Automatic Identification System (AIS) demonstration for COM DEV. The success of NTS led to the creation of exactEarth, a leading provider of ship tracking solutions internationally.

SFL broke more barriers with the launch of AISSat-1, a 7-kg ship tracking satellite for Norway. AISSat-1 was the first 7-kg satellite

AISSat-1 was the first 7-kg satellite to have full three-axis attitude control and also represented Norway's first operational satellite in orbit. Based on its success, a subsequent satellite, AISSat-2, was ordered and launched, marking the beginning of a Norwegian constellation of ship tracking satellites

to have full three-axis attitude control and also represented Norway's first operational satellite in orbit. Based on the overwhelming success of the first satellite, a subsequent satellite, AISSat-2, was ordered and launched, marking the beginning of a Norwegian constellation of ship tracking satellites. EV9 (exactView 9) was developed for exactEarth with advanced ship tracking technology and is believed to be the smallest satellite to have operational ground target tracking capability.

BRight Target Explorer (BRITE) Constellation is the world's first space astronomy constellation with high precision pointing capability (12 arcsec RMS), believed to be a first for satellites this small. The five-satellite constellation is comprised of satellites funded by three countries: Austria, Poland and Canada. Scientific discoveries are being published with BRITE representing the only high-precision means available to study luminous stars in the galaxy.

Finally, CanX-4 and CanX-5 represent the world's first 7-kg precise, autonomous formation flying satellites, having completed their mission in only four months after launch. Relative position determination was demonstrated with precision to a few centimeters, while relative position control was accomplished to the sub-meter level. Formations ranged from 50 to 1,000 meter separations.

SFL has additional satellites under development that are expected to launch soon (Figure 2). At 15 kg, NEMO-AM is India's first aerosol monitoring satellite to assist in measuring pollutants that directly affect quality of life and climate change. GHGSat-D is a 16-kg satellite with the mission of measuring greenhouse gas (GHG) emissions over targeted sites, to assist site owners with measuring, reporting and controlling their emissions.

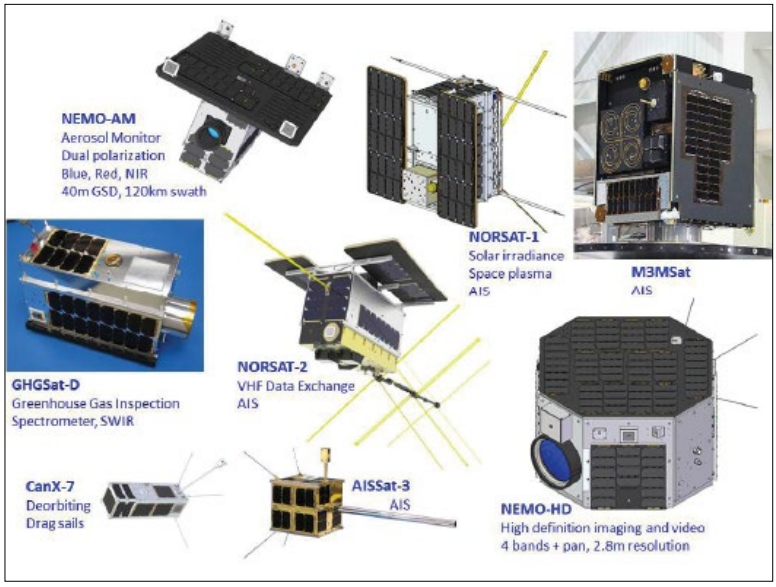


Figure 2: SFL satellites launching soon (as of Feb 2016)

This satellite will lead to a commercial constellation for GHGSat that will provide GHG target monitoring services globally. CanX-7 is a 3.5-kg satellite that will demonstrate deorbiting drag sails for debris mitigation purposes — instrumental technology to assist with regulatory approvals and to ensure small satellites do not contribute to the growing debris problem in space.

NORSAT-1 is Norway's first scientific satellite, measuring total solar output, studying space plasma, and using an advanced AIS receiver to track ships. Also at 16 kg, NORSAT-2 is poised to be the world's first VHF data exchange satellite. This will augment AIS detection with higher bandwidth two-way ship messaging capability. AISSat-3 is the third AIS satellite in Norway's AISSat Constellation with the latest advance in AIS receiver technology.

M3MSat is an 80-kg satellite developed for high bandwidth, high detection-rate ship tracking for the government of Canada. NEMO-HD is a 72-kg earth observation satellite for Slovenia, observing in four spectral bands, and pan-sharpening to 2.8m true resolution. The compact 60x60x-30cm NEMO-HD will provide high definition images and video to monitor land and coastlines.

Throughout its history, missions have been flown that exceeded the state-of-the-art at the time. SFL's mandate is to break barriers but also to do it in a way that surprises the market in terms of data capacity, computational agility, power density, attitude control accuracy and precision, at prices that are amenable to tomorrow's mass production needs for commercial constellations.

Commercial business models are sensitive to cost, and SFL solutions allow businesses to close financial models for new satellite services. Government programs worldwide have benefited from SFL's low cost missions, enabling them to operate in space for a fraction of the traditional cost and to accomplish big things within small budgets.

Dr Robert E. Zee,
Director, Space Flight Laboratory
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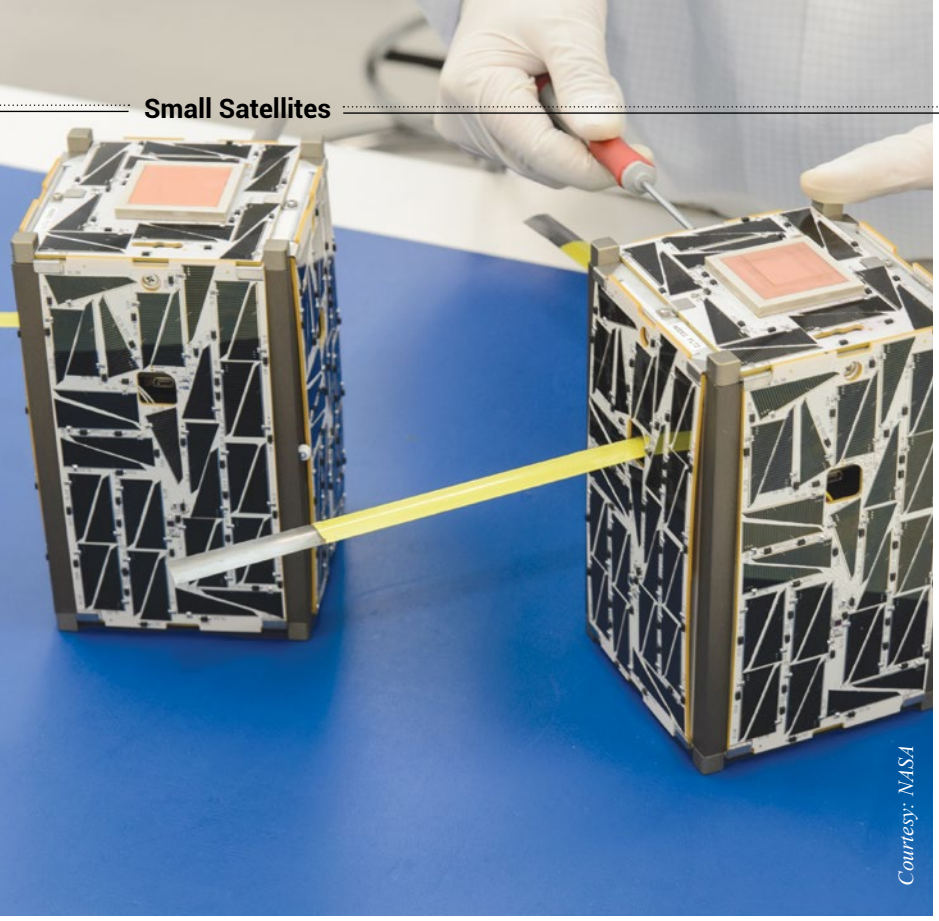


Courtesy: NASA

The Data Policy Pieces of the Puzzle

The outcome of the data policy debates, which could yield new access rules for some users, may require updating existing bilateral and multilateral data sharing agreements.

By Laura Delgado López

A key trend in the theme of disruption is the proliferation of small satellites, which include a range of classes with low size and mass, typically 500 kg or less. With new operators planning to launch hundreds of such spacecraft in the coming years, smallsats are projected to have a lasting impact on space activities. Beyond technological innovations, the rise of smallsats has been marked by tensions in the larger policy framework governing space activities. In particular, the potential for smallsats to assume critical tasks in earth observations has raised questions that touch on issues as diverse as defining stakeholders' roles and responsibilities, oversight and licensing, and safety of space operations. The solution to many of these issues requires policy, law, and regulatory mechanisms and is critical to balance the benefits and challenges of this technology.

A good case study to examine the variety of issues involved is the emergence of commercial providers seeking to supplement earth observation research and operational needs in the United States. The integration of commercially provided data sources into what have traditionally been government-run data flows, such as weather, appears particularly attractive in an era of budgetary constraints. For supporters of this shift, few issues have caused more headaches than data-sharing policies and their perceived risks to the burgeoning commercial weather data market. A more holistic approach to data issues could help inform ongoing discussions about how best to take advantage of the smallsat disruption in the United States and abroad.

Beyond a demonstration platform

Smallsats have been around for at least 30 years, but new manufacturing techniques and off-the-shelf technology solutions are transforming them to be the go-to option for established and emerging actors alike. The number of smallsats launched in the past few years seems modest when compared to the planned constellations: a 2015 Euroconsult report estimates 100 smallsat launches per year in the next five years, a two-thirds increase in the average annual rate of the previous decade.

No longer simple demonstration platforms, smallsats are being tasked for missions spanning research, operations, and services. This is due to characteristics like higher revisit time, shorter development cycles, and lower launch

costs than conventional larger satellites. In the plans of about 20 US-based remote sensing smallsat companies, potential users see more real-time data for improved weather forecasts and sustained, multi-sensor observations for greater geospatial intelligence at the local and national level. Changing government demand is also helping along the push of this technology.

Data policy pieces

The influx of new sources of information about the planet necessarily prompts questions about the policies governing their use. These questions should be examined from multiple angles.

► **Accessibility:** Clarity of access is a key requirement for efficient data utilization. Today's most valuable geospatial products and services are often created by combining multiple datasets from a variety of sources around the globe. However, the combination of multiple datasets adds several layers of complexity, even before including commercially owned sources. At a glance, high-level statements of open data access may seem straightforward and sufficient to meet objectives. However, in a recent survey of over 20 legal and policy documents related to earth observations data published in *Space Policy*, Ray Harris and Ingo Baumann found a lack of consistency in the use of the terms "free," "full," and "open," and numerous, often undefined, exceptions. As the Centre for Spatial Law and Policy's Kevin Pomfret argued in a recent geospatial law seminar, data policy issues inherently include difficult legal questions. As complex access rules are tested and applied, and different licensing structures are combined to account for new, commercial data sources, legal and practical uncertainties could severely hinder data utilization. Consequently, clarity of data access should be an essential consideration for providers of data, value-added services, and geospatial information platforms.

100

smallsats to be launched per year in the next five years

► **Reusability:** Potential reuse restrictions placed on commercial raw data and models have prompted heated debates in the United States — particularly with respect to meteorological data, historically shared globally among all users. Resolving the legal limitations on the commercialization of government weather satellites, as well as the interpretation of US adherence to the World Meteorological Organization's Resolution 40 requiring full and open sharing of "essential" data, will be needed to determine the viability of this emerging market. However, the consequences of this discussion on the existing commercial weather prediction sector are less understood. The multi-billion dollar private weather industry in the US depends on the rapid release of data acquired from government-operated sensors to develop tailored weather products and services. The economic impact of this sector has motivated others to adopt commercialization as a goal of investing in government earth observation programs and to promulgate open access data policies, such as the European Union's Copernicus program.

► **Archiving:** Over four decades of sustained earth observations have created an invaluable repository of insight about our changing planet. When combined with other kinds of information, these historical datasets play a key role in scientific research and in applications as diverse as public health, urban planning, and education. While several commercial smallsat operators have expressed a commitment to full data access to researchers and educational institutions, questions related to data archiving have not been sufficiently addressed. For example, in the medium and long-term, new and more frequent observations of key atmospheric variables will be significant additions to climate data records required by researchers and the emerging climate services market. Once weather data complete the operational stage, data policies should ensure that these remain discoverable and usable for trend analysis, thus requiring discussion of practical aspects like metadata standards, and database maintenance practices.

33%

increase in the average annual rate of smallsat launches over the previous decade

Evolving data policy

This brief discussion suggests a number of data policy-related issues raised by smallsats that should be integrated into ongoing discussions within government, industry and academia. True stakeholder engagement increases the likelihood that spillover effects are taken into account, such as benefits that go beyond those initially served by existing policies.

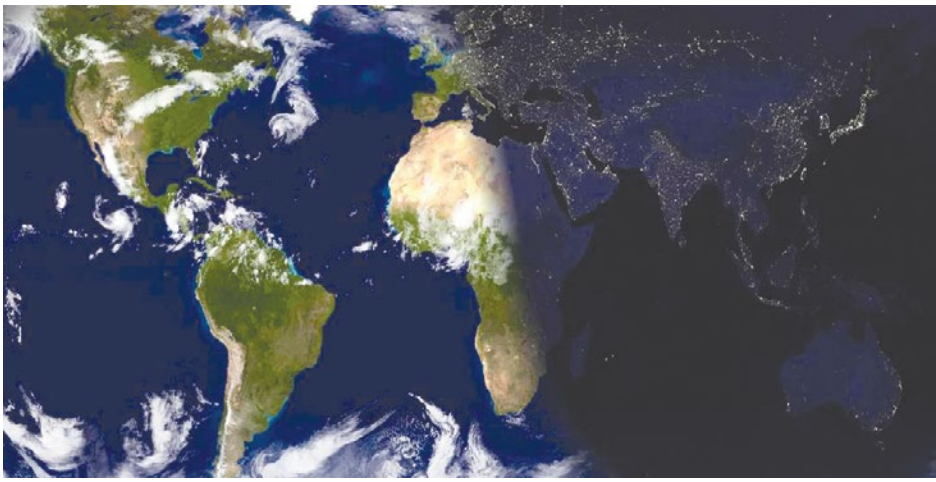
The international dimension of this conversation is particularly relevant. The outcome of the data policy debates, which could yield new access rules for some users, may require updating existing bilateral and multilateral data sharing agreements. Perhaps more importantly, these decisions may inform similar policies in other countries where smallsats are also booming. Considering the larger effects of setting new precedents presents an opportunity to evolve data policy to meet the growing demand while maintaining the positive trend of collaboration to address-shared challenges.

Laura Delgado López, Project Manager, Secure World Foundation
ldelgado@swfound.org

Introducing Innovation into WEATHER DATA MARKET PLACE

Emerging capabilities of small satellite constellations, commercially built and constantly refreshed, will make weather data affordable, more impactful, and ultimately create millions of new data points.

By Timothy Puckorius and Dan Stillman



With thousands of satellites, and airborne and surface-based sensors constantly taking the pulse of our planet, weather forecasting has been fueled by Big Data since long before 'Big Data' was even a thing. And yet, today's weather forecast still lacks the reliability required by the disaster response team positioning its precious resources, the electric utility predicting power demand, the commercial airliner optimizing flight paths, and the average citizen planning a weekend getaway.

A closer examination reveals why this is the case: despite the seemingly ample amounts of weather data collected, much of it never makes it into the forecast models, and most of it misses the inner workings of our atmosphere that have the largest impact on the weather we experience. In large part, this failure to adequately sample the atmosphere can be traced back to a decades-long lack of innovation in weather satellites that has us launching yesterday's technology today — a troubling trend that commercial industry is set to turn around in a big way.

On the face of it, the amount of environmental data collected each day is mind-boggling massive — over 20 terabytes by the National Oceanic and Atmospheric Administration alone. That equates to 1,200 piles of typed paper, each stacked as high as the Eiffel Tower, or more than double the total printed collection of the Library of Congress. The world of weather forecasting has surely benefitted from the ever-increasing environmental intelligence gathered about our planet — the vast majority of it now from satellites — with today's five-day forecast about as accurate as a three-day forecast was 20 years ago.

However, we still lack the data necessary to routinely predict high-impact weather events with adequate accuracy and lead times. We see this year in and year out with snowstorms along the East Coast of the United States, with widely varying forecasts even less than 24 hours before the first snowflakes arrive. We see this with hurricanes as

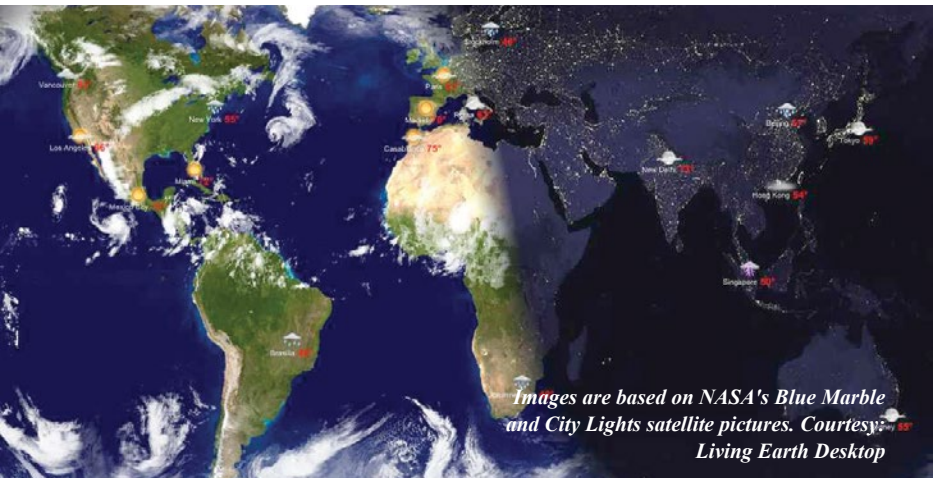
well, with last fall's Hurricane Joaquin the most recent example. Model projections showed Joaquin striking anywhere from South Carolina to New Jersey, when ultimately the storm did not make landfall at all, tracking well off the coast despite contributing to historic flooding in South Carolina.

The missing links

With so many observations from a multitude of space-based, ground and airborne instruments being funneled into increasingly advanced weather models powered by more and more computing capacity, why do we still struggle to accurately predict the most impactful weather events with the lead times necessary to properly prepare and protect property, lives and businesses?

One major reason is that, despite the deceivingly large amount of data collected on a daily basis, the vertical structure of our atmosphere is still severely under-sampled. Large, billon-dollar weather satellites, flown by a handful of major government space programs around the world, provide crucial data for weather forecasting. Yet their vertical resolution — that is, the distance in altitude between data points — is typically no better than 1 to 3 km, which is an order of magnitude too coarse to see small-scale changes that can have huge impacts on our weather. Not to mention, many of the existing sensors can't even see through clouds. That is a lot of missing data given that, at any moment, about two-thirds of the Earth is covered with clouds.

A true 3-D cat scan of our atmosphere would reveal sharp changes with altitude in temperature, pressure, humidity and other variables. These vertical gradients determine the stability of the atmosphere, which has profound impacts on the development of clouds and storms. However, our ability to observe the detailed structure of the vertical atmosphere is currently limited, primarily to about 900 weather balloons sparsely scattered across the globe and launched only once or twice per day. Furthermore, the vast majority of these balloons are launched over land, whereas most weather systems originate over the ocean, and very few balloons cover the developing world, remote areas or the poles.



Images are based on NASA's Blue Marble and City Lights satellite pictures. Courtesy: Living Earth Desktop

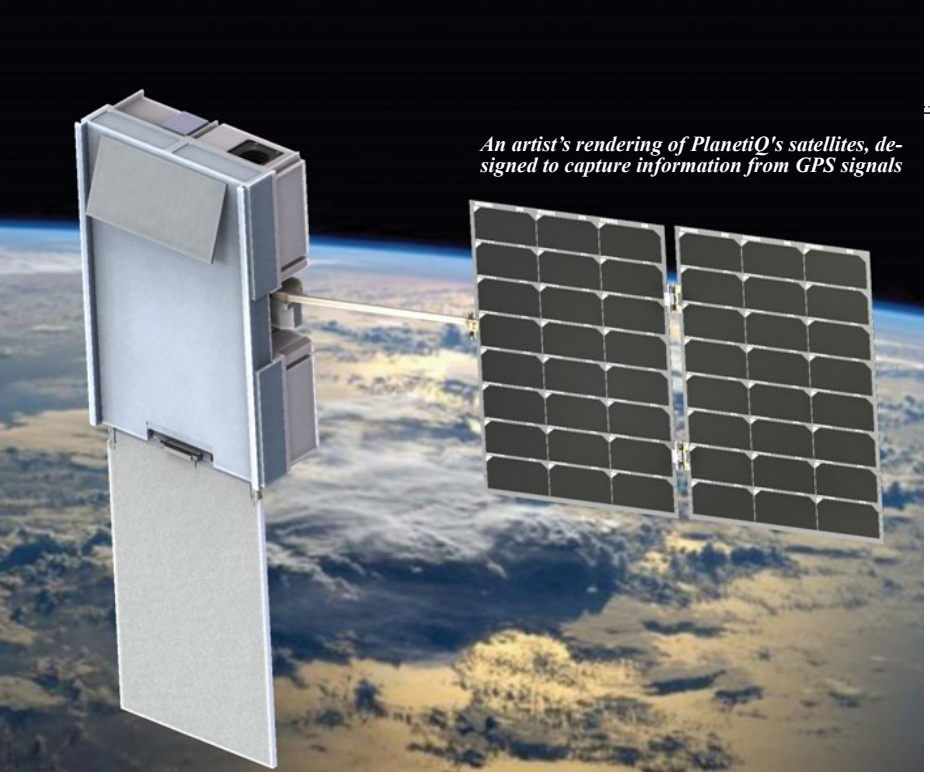
How smallsats can change things

Enter the emerging capabilities of small satellite constellations, commercially built and constantly refreshed. From low-earth orbit, our much lighter and less expensive satellites will drastically increase the number of vertical atmospheric profiles collected each day, with observations approximately every 100 meters in altitude from the Earth's surface up into the ionosphere. That equates to over 8 million observations per day of temperature, pressure and moisture, which will dramatically improve forecasts for all kinds of weather, and especially for storms that do the most damage to people, property, and the bottom line of numerous businesses in numerous sectors.

As an industry, it is critically important that we deliver not just on the quantity of data promised, but also on the high quality of data required by numerical weather prediction centers worldwide. That is why despite their small size and low power requirements, our satellites will carry the only sensor of its kind that is powerful enough to probe all the way down into the lowest three kilometers of the atmosphere and to the surface, where most of our planet's weather occurs, and are designed to last seven years or more. After all, poor-quality and unreliable data, no matter how much of it, will only serve to degrade the forecast, not improve it.

There is a precedent for the kind of commercialization we are now witnessing in the area of space-based atmospheric weather data. In fact, there are several examples in which solely governmental satellite and space activities transitioned to a team effort, with the commercial sector

Despite the deceivingly large amount of data collected on a daily basis, the vertical structure of our atmosphere is still severely under-sampled



An artist's rendering of PlanetiQ's satellites, designed to capture information from GPS signals

augmenting government programs that had often fallen behind, lacked innovation and seen costs skyrocket. Satellite telecommunications was the first to undergo such a transition, starting as far back as the 1960s. The most parallel example, though, is that of satellite imaging.

Private sector to the rescue

When an aging and overworked fleet of government satellites led the demand for satellite imagery to outpace supply about 15 years ago, the US government partnered with the private sector to promote a commercial industry for earth observation. Soon it was the likes of DigitalGlobe and GeoEye that were not only fulfilling the mission-critical needs of the defense and intelligence communities, and doing so in a more cost-efficient way, but also laying the groundwork for the online and mobile mapping tools we can't imagine living without today.

And now it is a new generation of maturing start-ups, including Planet Labs and Terra Bella (formerly Skybox Imaging), that are starting to image the world with swarms of small satellites that can provide the rapid refresh rates needed to support a host of new applications. The launch frequency required for such constellations will be aided by the emergence of SpaceX, Virgin Galactic and other space launchers — yet another industry that, only a decade ago, was solely the purview of governments.

In a strikingly similar situation to that of satellite imagery a decade and a half ago, today's government weather satellite programs are delayed and over budget, with data gaps already occurring, and innovation hamstrung by competing budget priorities and development cycles that last 10 to 15 years from requirements setting to launch. There is an alternative to this status quo, however, and it's in the form of a commercial weather satellite industry now poised for rapid growth. Much as it has done for satellite imaging, the commercial sector's miniaturization of space-based sensors and components will enable the launch of many more weather satellites for a much lower price.

Opportunities galore

The result will be a dramatic increase in atmospheric data worldwide, which when coupled with steady improvements in weather and climate modeling, increasing computing capacity, and the emergence of new tools for custom-tailored analytics, promises an unprecedented increase in the quantity and quality of actionable information supporting the government, energy, agriculture, insurance, transportation and retail sectors, to name a few. Only now are we beginning to fathom the magnitude of social and economic benefits possible from better forecasts of hurricane tracks, optimized ship routing, reduced spending on aviation fuel, more efficient agriculture practices, and many other applications.

In some ways, the market opportunity for satellite weather data may even exceed that of imagery. Not just because our weather seems to be getting more extreme, or that businesses and entire industries are increasingly recognizing the value of weather and climate information in reducing risk and making better decisions. But also because, by its very nature, weather data is perishable. Almost as soon as an observation is collected and delivered into a weather forecast model, the next forecast cycle requires a fresh look at the latest conditions.

It is this growing demand for precise and frequent data, with dense global sampling from the top of the atmosphere down to the Earth's surface, that has set the stage for a transformation of the satellite weather data marketplace. As other industries have proven before, commercial augmentation of government systems will make weather data more affordable, more impactful, and ultimately create millions of new data points to support numerous sectors with the information they need to better prepare for whatever Mother Nature may offer next.

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Birds of a FEATHER

Location as a Service helps retailers measure customer demographics and store performance.

By Helen Thompson

The proverb "birds of a feather flock together" describes how those of similar taste congregate in groups. We live in neighborhoods in which we share many similarities with our neighbors. Yet, when we look further at the level retailers want for mass personalization, people can be more different than they are similar. The same is true for groups of customers, markets, trade areas and neighborhoods. These variations, individual activity, lifestyle, neighbors and place, are the key to unlocking a better understanding of shopping patterns and observed behaviors.

But how do we find out what's really important to customer activity and store performance? It will require new ways of thinking about the way large enterprises provision location infrastructure and whom they empower with it. Retailers are increasingly realizing that to move from the technological and knowledge silos of cross-channel and multi-channel to omni-channel they need to be able to more effectively apply context and activity at scale. Location-enabled data and the insights gained by analyzing it with dedicated spatial models and what-if scenarios brings deeper understanding of customer touch points and expectations. This is especially true in making sense of purchasing, home delivery and product assortment.

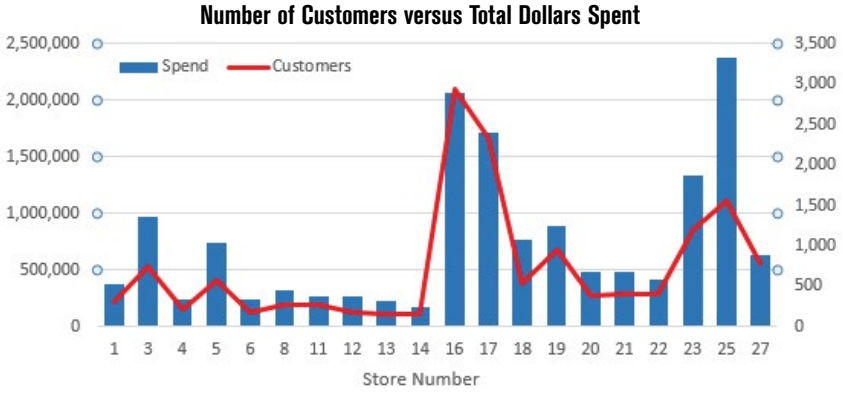


Figure 1 shows the customer relationship management, who have been mapped with their corresponding attributes such as preferred store, total annual spend, delivery location, etc

Consumer behavior continues to evolve and change. Today's rate of change is an order of magnitude faster than three years ago driven by new technologies, affluence, availability and expectations. Business models and operations must change but often retailers struggle to identity how to change and the infamous failures which make the headlines in the press make retailers more nervous and cautious. They know they need a more sophisticated response if they truly want to impact the customer experience. I believe it's time retailers started using real location insight to deliver on all those expectations — from boardroom and investors to customers.

Integrating Location as a Service (LaaS) enables retailers to work more collaboratively and turn location-based data into answers to business questions. Let's look at an example in the San Francisco Bay area using LaaS. Location data is far more prevalent and powerful than most retailers realize. It's not common to think of the buying

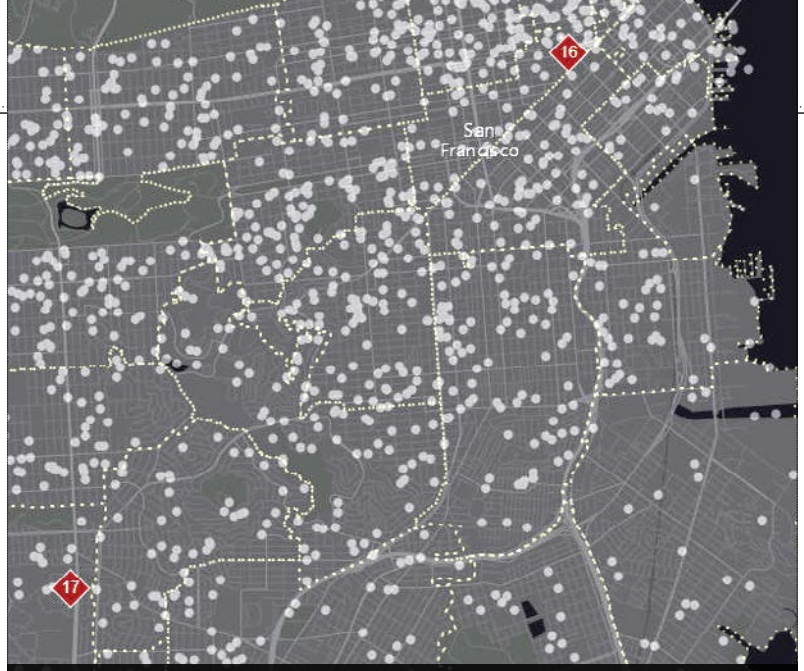


Figure 2 shows thousands of individual customer transactions have been used to create a map of total sales (high in red)

Different variables create different surfaces of spend, supply, demand and market opportunity that make up the basis of retail models. Individual customer points can be aggregated to heat maps, ZIP Codes, sales territories, Census areas, States, MSAs or any unit of geography a retailer desires

and selling process as happening because of where, so location data management and analysis are not at the center of most retail business activities. To compound things, none of the enterprise systems that most retailers use have not been designed to truly create, manage, and share location based insight.

Where are my customers?

In Figure 1, a store has over 14,000 customers in the customer relationship management (CRM) who have been mapped with their corresponding attributes such as preferred store, total annual spend, preferred method of payment, purchase channels, number of items purchased and delivery location. Every one of these attributes can be used to form a better picture of who customers are, where they shop, what they and their neighbors look like, and how goods and customer service can be improved to deliver higher loyalty and profitability from every customer.

Customer density

We can create a heat map of where customers are located to show concentrations. Any attribute can be used to calculate these density surfaces which are the basis of retail demographic analysis. Understanding the characteristics of customers, who they are, what they want and what else they might need allows retailers to better plan their products and services.

Different variables create different surfaces of spend, supply, demand and market opportunity that make up the basis of retail models. Individual customer points can be aggregated to heat maps, ZIP Codes, sales territories, Census areas, States, MSAs or any unit of geography a retailer desires.

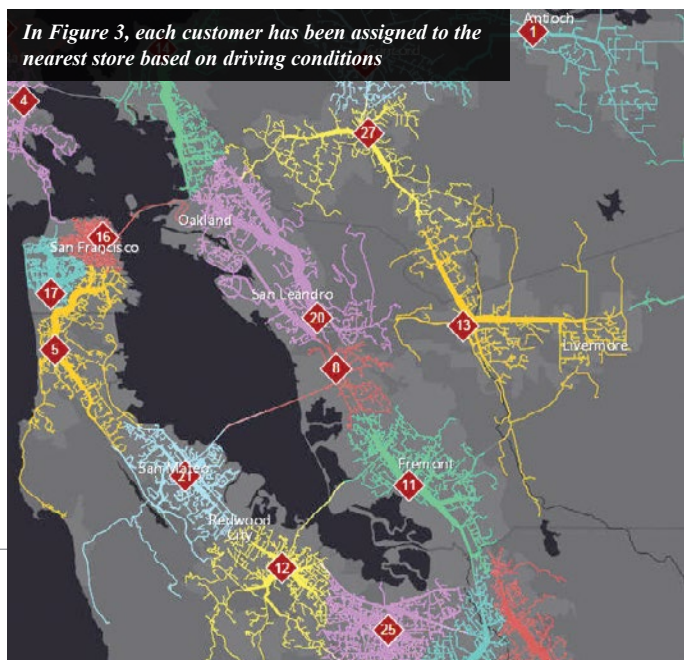
Aggregation creates scores and summaries that can be used as inputs to other models and analysis. In Figure 2, thousands of individual customer transactions have been used to create a map of total sales from low (around $15,000) in blue to high ($135,000 and more) in red.

The nearest store

Customers could visit their nearest store, creating beautiful patterns of roads with the store in the center. In the real world, people travel and shop for many different reasons. They may shop near where they work, or make a special trip to a flagship store. Regular mall trips may be part of the weekly or monthly shopping. There are any number of reasons based on habits, activities and preferences.

In Figure 3, each customer has been assigned to the nearest store based on driving conditions. Each customer journey, between home base and the store, is broken into the individual roads used to get there. Each time a segment of road is used in a trip, it is counted so every road has the number of customers who would potentially use that road to get to the store. This creates a beautiful,

In Figure 3, each customer has been assigned to the nearest store based on driving conditions



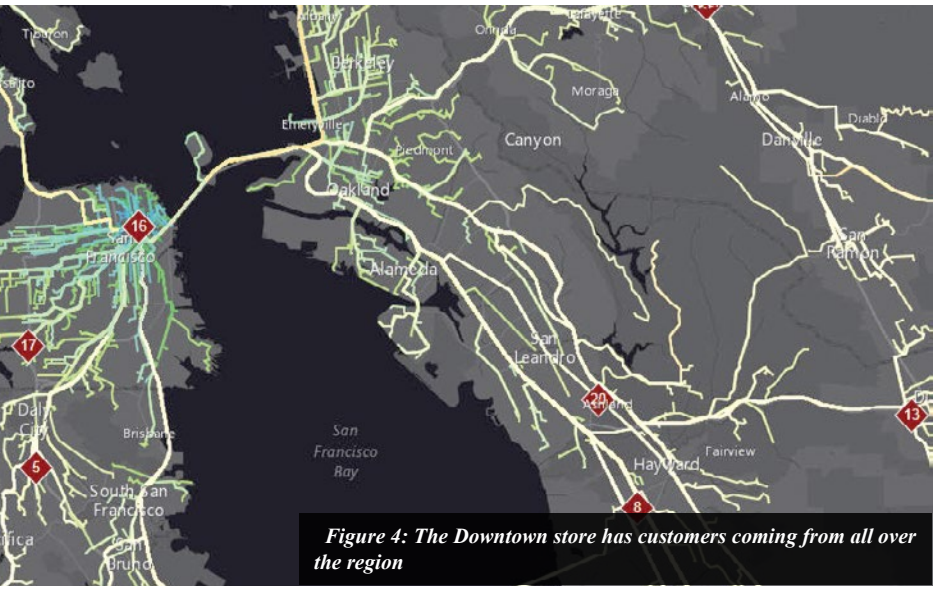


Figure 4: The Downtown store has customers coming from all over the region

organic pattern of dendritic roads as many different journeys feed into the same locations as customers get nearer to the store.

Purpose dictates purchase

People shop at stores for many different reasons. The store may be convenient from work, close to a point of recreation or as part of another activity. How, why and where people shop is complex.

In Figure 4, the Downtown store has customers coming from all over the region; many traveling for over an hour. Notice how major roads build on each other and the time taken to get to the store also varies by road type and potential maximum speed.

Connecting stores to customers' homes

The top 5 stores in Figure 5 paint a complex pattern of interconnection between the customers' home base and where they shop. Here we are looking at the third, fourth and fifth most popular stores.

How do these stores differ in the people they serve, where those people come from and how far they are willing to travel? Can factors like demographics, spending behavior and liveability explain customer and store interactions?

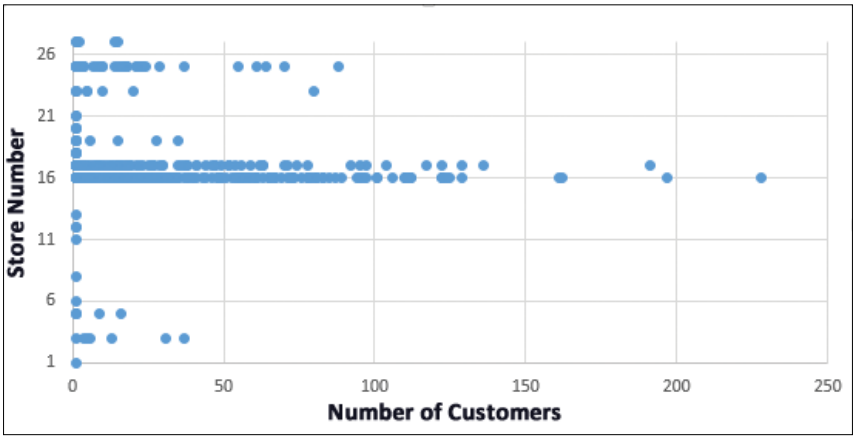
Getting to know you

Esri Tapestry Lifestyle data helps retailers understand their customers' lifestyle choices — what they buy, and how they spend their free time. Tapestry (Figure 6) classifies US residential neighborhoods into 67 unique segments based on demographic and socioeconomic characteristics. It enables retailers to get more insights on their best customers and underserved markets, conduct better marketing campaigns with higher response rates and turn less profitable areas into success stories.

Customer spending for each ZIP Code can be aggregated and analyzed against the dominant Tapestry segmentation group. Laptop and lattes are concentrated downtown, while Pacific Heights residents can be found in Daly City and enterprising professionals tend to be found near Sunnyvale. There are other distinct pockets — can you see where trendsetters like to hang out at home or the urban chic neighborhoods?

Educational attainment is often assumed to correlate with high disposable incomes and high spending but is this always true? In Figure 7, customer spend is shown using increasingly large circles and the circles are colored by the proportion of residents having a Bachelors' Degree or higher. The distribution ranges from 8% (red) to 88% (green).

Neighborhoods around Store 19 in San Jose show low levels of degrees and low store spending. Downtown areas have high concentrations of degrees but only average spending — perhaps they are servicing expensive apartments — while Sunnyvale has highly educated people and above average spending.



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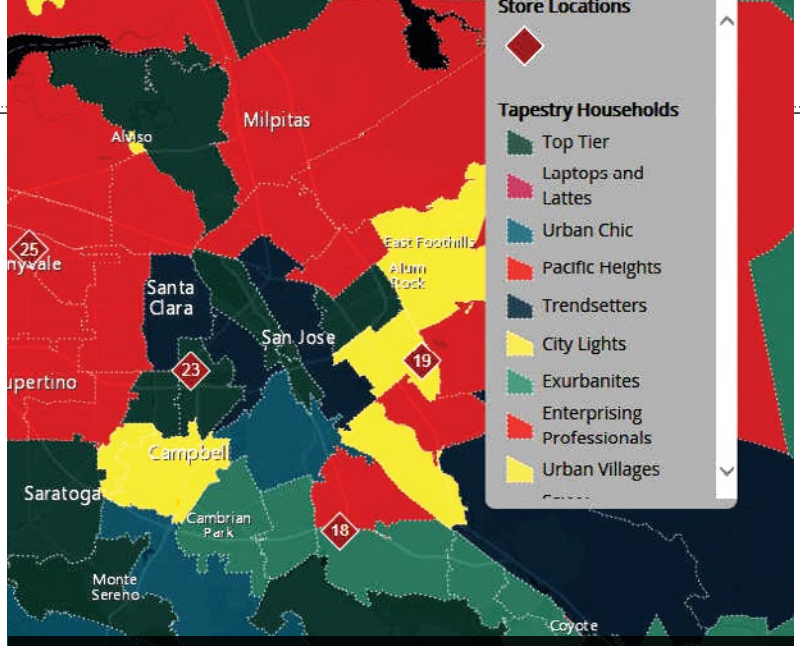

Figure 7: Customer spend is shown using increasingly large circles and the circles are colored by the proportion of residents having a Bachelors' Degree or higher

Spending and population density

Urban areas have much higher population densities than the suburbs. Downtown San Francisco has densely packed pockets and its famous Queen Anne homes around Alamo Square with beautiful bay windows, turrets, and decorated rooflines. Housing density impacts house size and affordability. Here average spend per customer (size) is mapped against population density (color). Generally spending increases away from the denser multi-story and multi-family downtown areas towards the more spacious suburbs.

Oakland and San Francisco highlight different patterns in lifestyle and spending behaviors. Oakland is dominated by trendsetters and city lights compared to the laptop and latte segment in San Francisco. All segments live in high-density areas but trendsetters tend to spend more on living life to the full and city lights will commute long distances to support their lifestyle. Each segment is summarized in Figure 6.

Wendy's: Putting Lifestyle data to the test

Wendy's, the world's third-largest quick-service hamburger chain, integrates the Esri ArcGIS platform and Tapestry Lifestyle data with the restaurant's corporate IT systems. The Web-based business GIS solution is part of the company's reporting system for new locations, assisting in site selection and market analysis.

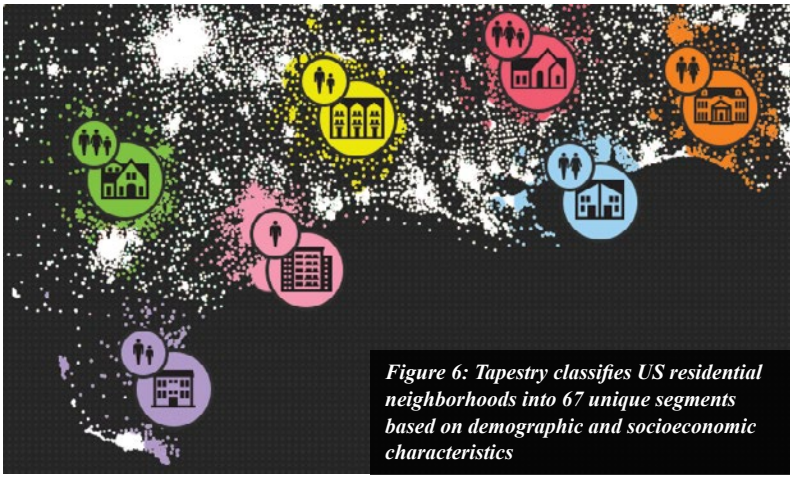

Figure 6: Tapestry classifies US residential neighborhoods into 67 unique segments based on demographic and socioeconomic characteristics

The company feels demographic data and location analytics are critical components when making investment decisions to build new restaurants. Everything they need — including mapping, analytics, and modeling — can be done on one platform that is scalable across their organization. And their organization is significant — the Wendy's chain includes more than,500 franchise and company-operated restaurants in the United States and 27 countries and US territories worldwide.

ArcGIS replaces a current system in use at Wendy's. Implementation was completed by Esri business partner GIS, Inc. located in Birmingham, Alabama. The new solution includes server GIS applications, Esri demographics data and customized analytics developed specifically by GIS, Inc. to streamline and enhance Wendy's site screening and market assessment process. Staff can easily view sales records, customized demographics and other business reports on existing restaurants through an intuitive mapping interface. The system also enables Wendy's to perform predictive modeling and assess potential restaurant cannibalization for new and existing sites by simply clicking on the map.

Drive your own strategy with location as a service

As we have seen, retail is a location-centric business. Every customer can be analyzed and connected to every action by location. Use Location as a Service to connect your products and services with your customers. You will see new patterns emerge from oceans of data and show the underlying journey to purchase.

Helen Thompson, Director, Commercial Marketing, Esri
hthompson@esri.com

The Big Data movement has the potential to be enormously helpful to the location industry by allowing GIS experts to come out of the backroom and take the main stage, says **Tony Boobier, Worldwide Executive with IBM Analytics.** In his current role, Boobier focuses on the partner ecosystem and the increasing influence of disruptive technology on established business models

LOCATION ANALYTICS HAS MATURED OVER THE PAST DECADE

What exactly is IBM doing in the field of location analytics?

There is a need to provide industry-specific, relevant solutions which meet the needs of the business user as opposed to simply placing generic technical capabilities on the table and hoping some of them will be useful. Location analytics as a general topic has increased in maturity over the past decade especially as GIS has come out of the backroom, and has increasingly taken its place in the overall analytics story. It is easy to suggest that GIS is just another dataset but that fails to take into account the criticality of understanding 'place' in many different contexts.

IBM takes location analytics seriously, not only in the context of many competing and valuable data sets, but also in an environment of rapidly emerging and disruptive technologies.

Which are the industries that can benefit from location analytics?

There are obvious industries which can benefit, such as, retail, banking, insurance, agriculture and the like. In fact, it is more difficult to think of industries which are unlikely to benefit — even dentistry has a location component as it relates to lifestyle, diet and tooth decay.

Perhaps a different approach is to examine the topic from a higher level viewpoint, for example which industries are most likely to be impacted by the 'connected home'. The 'connected home' will inevitably have a location component which will be of interest to retailers, utilities, insurers, insurers and others. It is also tempting to think about the 'connected person' and the 'connected factory', and of course the idea of the 'connected car' is increasingly becoming mainstream thinking. Perhaps the location component is the 'golden data' that unites all these different industries around single issues.

What sort of data do you tap to get to insights from location analytics?

Data is categorized into structured data and unstructured or 'dark' data. Dark data is the data that comes from devices, video, voice — and almost all of these have a potential location

component. The increased availability of open data adds yet more information to the mix. Our 'Analytical Exchange' provides an open data exchange that includes a catalogue of more than 150 publicly available datasets that can be used for analysis or integrated into applications, including geospatial data.

How does location analytics fit into the Big Data movement?

Although we think of this as a 'movement', neither data nor analytics are the destination but rather they provides insight which helps organizations ensure that they are on track to meet their business objectives, and to make adjustments if needed. By the same measure, having effective location analytics is not the destination, but is a capability which helps organizations (and individuals) meet their objectives.

The Big Data movement has the potential to be enormously helpful to the location industry by allowing GIS experts to come out of the backroom and take the main stage. That requires those GIS experts to understand and be able to talk to the business issues, and not hide behind technical capabilities and jargon.

How do you plan to leverage analytics in the area of connected cars?

Many organizations started with niche vendors on proof-of-concepts. Increasingly, we are seeing a trend towards more strategic and substantial relationships with robust partners who have cutting-edge technology focused on the Internet of Things. We are also seeing the need for modular design architecture which allows a holistic view of the technical requirements yet allows scope for differentiation. Although telematics is of considerable interest to the insurance sector, it goes far beyond this. Ford recently described themselves as 'no longer an automotive company' and have recently joined forces with IBM to accelerate how Big Data is used with cars.

> Having effective location analytics is not the destination, but is a capability which helps organizations meet their objectives

We also recently announced Germany as the global headquarters for our new IoT unit, as well as its first European cognitive innovation center. The campus environment brings together a thousand IBM developers, consultants, researchers and designers to drive deeper engagement with clients and partners. It will also serve as an innovation lab for data scientists, engineers and programers building a new class of connected solutions at the intersection of cognitive computing and the IoT. Overall it represents IBM's largest investment in Europe in more than two decades.

How has IBM's analytics architecture changed over the past few years?

Our analytics capabilities are now available 'as a service' or in the Cloud which helps organizations get up and running more quickly, as well as reducing the cost of development, deployment and maintenance. The level of interest in this may also be a by-product of the shortage of client-side analytical skills in the industry. We are also seeing a lot of excitement around the 'hybrid Cloud' where companies maintain their own data centres as well as using the Cloud. Some market researchers suggest that this will be an $88-billion market by 2019. We do not see hybrid Cloud as a transitional stage but rather that it is likely to be the approach that many companies choose to adopt going forward for the forseeable future

How does the recent acquisition of the Weather Company fit into IBM's scheme of things?

In the same way that location is infused into many business decisions, so too is the topic of weather. The ability to better understand weather conditions in the context of operational decisions, supply chain, risk, and customer demand all have validity and of course have a location element. Beyond this, Weather Company provides us with an operational platform which allows us to digest and process data from thousands of sources, resulting in 2.2 billion unique forecast points and on an average day 15 billion forecasts. Additionally it represents an interesting shift beyond IBM only analyzing third party data into being the owners of data ourselves.

What do you think will come next for location analytics as an industry?

Analysts anticipate that the IoT market will be about $400 billion by 2019. Data from many, if not all, of these sensors will have a location component, so it is pretty clear that location analytics is here to stay in one form or another. One thing that the location analytics industry is great at is in the creation of effective visualizations — we used to call them 'maps' — but the visual presentation nowadays is so much more important. I am waiting for a breakthrough in the visualization of location analytics.

I am also curious to see how the location analytics industry will cope with the changes being brought upon it by the cognitive era. Being able to apply analytics to unstructured data in a 'cognitive' manner will make the geospatial environment very different to what we know today. The next generation will grow up with cognitive analytics as 'the norm', and how will this change the skills of a future geospatial specialist? The geospatial industry has to think hard about in the future, and that thought process needs to have started already.

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Value of EO

As Australia's understanding of the capability of earth observing satellites matures, so will its use of EO data. **By Chris Penning**

Earth observations from space are the richest source of information about the Earth with the power to inform decisions and activities across as agriculture, mining, community safety and healthcare.

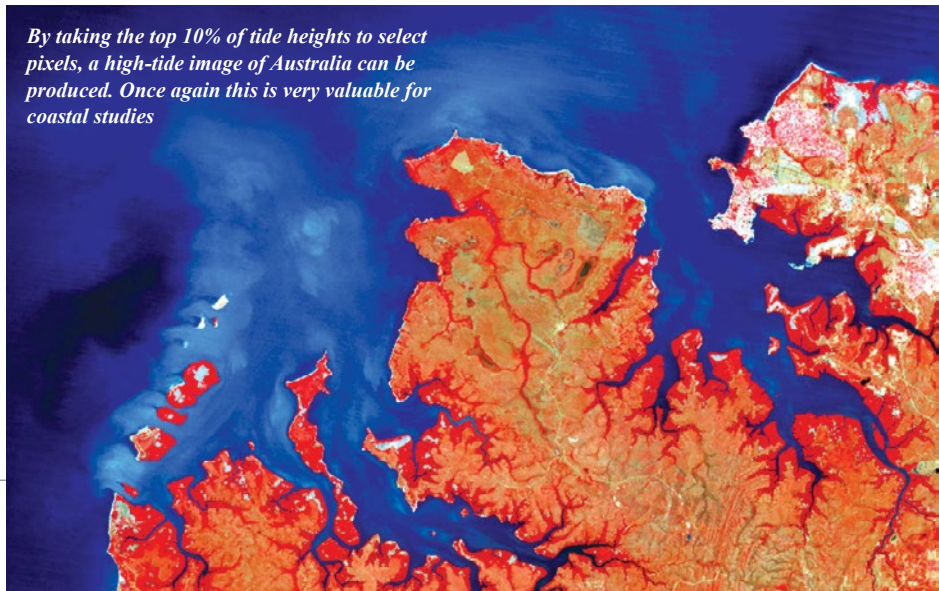
Australia is a significant user of Earth Observations from Space (EOS). The CRCSI-commissioned report, The Value of Earth Observations from Space to Australia (2015, ACIL Allen Consulting) found that EOS returns approximately A$5.3 billion to the Australian economy every year, and the use of EOS-services generated around 9,000 new jobs in 2015. The report predicts growth of up to A$8 billion, with more than 15,000 employed as a direct result of EOS services by 2025.

As Australia's understanding of the capability of earth observing satellites has matured, so has our use of EOS. Consequently, our dependency on EOS as a critical data source has increased. The soon-to-be published, Australian Government Earth Observation Data Requirements to 2025 report (2016, CRCSI for the Commonwealth Government) identified 140 government programs that employ EOS in activities such as: weather forecasting; disaster mitigation and management; climate and water cycle modelling; land use and land cover monitoring; forestry; carbon accounting; mapping inland and estuarine water quality; coastal habitats; seagrass and coral reefs; mineral mapping; hydrology; cartography and cadastral mapping; sea surface temperature; and biodiversity monitoring.

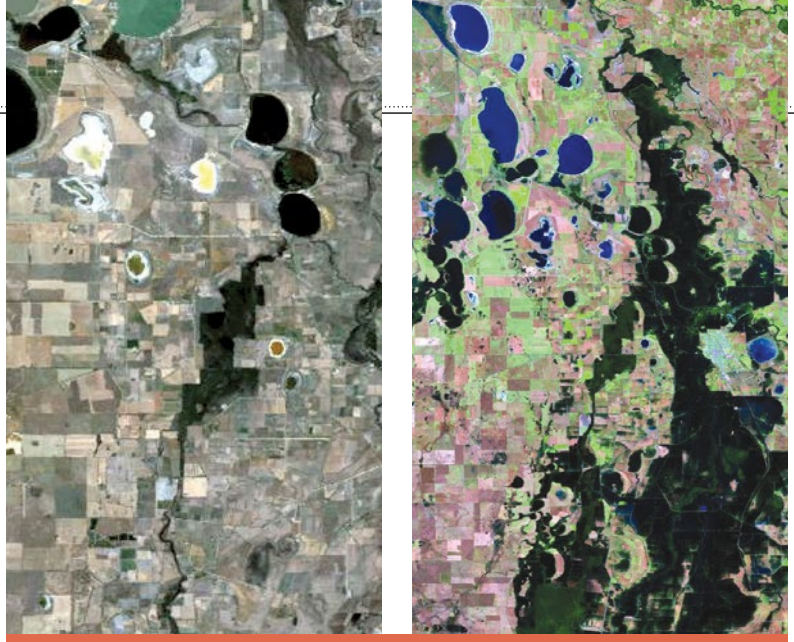
Data continuity risks

The critical nature of this data, and the risks to the continuity of its supply, was explored in detail in another CRCSI-commissioned report, the Risks of Data Supply of Earth Observations from Space for Australia (2015, Symbios Communications). The report found that in contrast to 2010, when the outlook for Australia's continued access to EOS seemed rather grim due to the failure of Landsat-5 and the absence of long-term European EOS programs, the picture in 2015 is far more positive.

The successful launch of Landsat-8 in 2014, and more recently Himawari-8, Sentinel-1A and Sentinel-2A, together with the adoption of a free and open data policy by the European Union, and the negotia-



By taking the top 10% of tide heights to select pixels, a high-tide image of Australia can be produced. Once again this is very valuable for coastal studies



These images show Kerang in Victoria. The image on the left was acquired on January 4, 2011. It is in 'true colour' which is roughly what we would see with the human eye if looking from space. The second image, taken 16 days later, shows the area in full flood. This image is in 'false colour' which enhances features in the landscape making vegetation and water much easier to distinguish

tion of a European Union-Australian Government strategic alliance, mean that Australia's access to EOS is not only assured, but that the main challenge for the future is how to deal with the vast amounts of data that will be available.

In 2011, the Continuity of Earth Observations from Space — Operational Requirements for Lands, Coasts and Oceans to 2015 (CEODA-Ops) report (2011, Geoscience Australia) projected the annual storage volume required for all data types, including three levels of processing, would be approximately 1.2 PB per year by 2015. However, updated analysis suggests that volumes of around 1 PB per year for unprocessed data alone, with a cumulative storage total of approximately 8.5 PB by 2025 can be expected. The additional volume required for data processing (3 levels) and back-up (2 copies) brings this cumulative total to approximately 42.5 PB by 2025.

Alongside continued engagement to ensure data continuity, Australia must plan for the vastly increased volumes of EOS expected to be available by 2025. New missions such as Himiwari-8 and Copernicus represent significant challenges to Australia's existing infrastructure and data management capabilities. Annual data storage volumes in the petabyte range are already required and will only grow as new sensors and missions come online in the lead up to 2025.

The need of the hour

Urgent action is required to put in place arrangements and systems for effective and efficient data management and analysis in order to realize the benefits of this huge volume of data. Ongoing action is required to lower the technical barriers to the application of the data, making it easier for industry to take full advantage of data that has traditionally been usable only by a very narrow group of technical experts. Australia must also continue to undertake the research and development to ensure the potential of the data is translated into the products and services it makes possible.

Despite Australia's dependence on EOS, Australia does not operate a single earth observing satellite, and relies entirely on data from satellites operated by foreign governments and the private sector. Even if Australia were to launch a number of its own missions to address specific priorities, it would still depend heavily on data from the international community to provide as complete a picture of the Earth, and how it is changing, as is required to support current, and future, products and services.

Australia's international engagement has increased significantly in recent years. The Australian Government has established strategic partnerships with the European Union, United States Government and the Japanese Government. State governments, universities, institutes and the private sector have also increased engagement and collaboration with international partners, reflecting the 'global' nature of satellite earth observation and the potential for work done in Australia to be translated internationally.

The Australian Government, through CSIRO, with support from Bureau of Meteorology and Geo-Science Australia, is also the 2016 Chair of the international Committee on Earth Observation Satellites (CEOS). CEOS brings together 35 space agencies, operating over 130 missions, to improve coordination for global benefit. A key goal of CEOS is to make it easier for EOS to be exploited by making it easier to use and combine data from different satellites. This ultimately makes it easier for Australian researchers to collaborate with overseas partners, for Australian government agencies to work with counterparts on big regional and global challenges, and most importantly create an environment where it is easier for Australian businesses to 'export' EOS-based products and services to other markets.

Links to Reports
http://bitly.com/RisksEarthObservations
http://bitly.com/ValueEarthObservations

Chris Penning, Project Manager,
CRC for Spatial Information, Australia

From left: Trimble CEO Steve Berglund, Rolta Chairman K.K. Singh, ISRO Chief A.S. Kiran Kumar and NASSCOM Chief B.V.R. Mohan Reddy with Geospatial Media & Communications Chairman M.P. Narayanan and CEO Sanjay Kumar at the release of the report ***Geospatial Technology in India: Trends and Opportunities***

INDIA ON A GEOSPATIAL HIGH

South Asia's biggest geospatial conferences, **GeoSmart India 2016 and GeoIntelligence Asia 2016**, focused on issues like smart cities, Digital India and the need for a national geospatial policy

With the Indian government's recent policy announcements like Digital India, smart cities projects, and National Rural Internet and Technology Mission, geospatial technologies can play a disruptive role by reducing costs, expanding access to services, delivering more consumer value and reducing inefficiencies. Which is why, geosmart infrastructure and geosmart enterprises were the buzzwords at the South Asia's two most coveted geospatial technology conferences — GeoSmart India 2016 and GeoIntelligence Asia 2016. The recently concluded twin conferences threw the spotlight on the potential of geospatial technology and its applications for India's development agenda and security.

Union minister and former Army chief Gen V.K. Singh, who was the chief guest at the awards distribution ceremony, made a passionate case for Make in India, saying the geospatial industry has tremendous growth scope in India and the government is aggressively working towards building a conducive environment in the country.

The need for a comprehensive national geospatial policy was also one of the foremost talking points. India's Deputy National Security

Adviser Arvind Gupta spoke on the need for a national geospatial policy and urged the industry to help the government draft such a policy. Underlining that India needs to focus on data access and availability, Gupta said even though the Indian geospatial industry has taken great strides, there still remains lots of untapped potential in the country.

Cyient Chairman B.V.R. Mohan Reddy, who is also the chairman of NASSCOM, the premier organization that represents and sets the tone for public policy for the Indian IT sector, said geospatial today is part and parcel of the IT. Giving examples like Uber and Airbnb, he pointed out how geospatial had become the backbone to mainstream industries. Therefore there was an urgent need for a well laid out national geospatial policy to address various loopholes in the system and encourage its use, he added.

K.K. Singh, Founder Chairman and CEO of Rolta, also called for a change in the highly restrictive mapping policies. Further, he spoke for more engagement of the private industry in PPP initiatives, which he felt would boost the uptake of geospatial further in every field.

Speaking at the opening session, ISRO chief Kiran Kumar said, India has for long used space technologies for development and nation building. With geospatial and location becoming inherent to businesses, the government focus on development will encourage its use further.

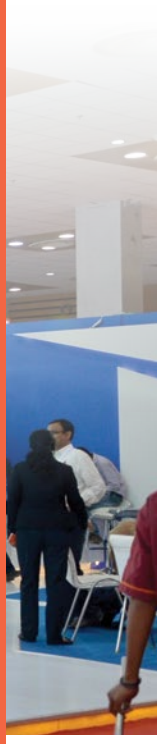
Why GeoSmart India

Previously known as India Geospatial Forum (IGF), GeoSmart India in its new avatar addresses the evolution, changes and innovation of geospatial technology in the region. Bringing together around 2,000 geospatial professionals and users from India, as well as from countries like the United States, Japan, Australia, United Kingdom, the Netherlands, South Africa, Singapore, Bhutan, etc., the conferences acted as hotbeds for deliberations on using geospatial technology in projects like smart cities, Digital India, internal and border security, disaster management, etc.

The three-day event connected diverse stakeholders of geospatial technology to engage and interact with each other to understand their needs, challenges, offerings, and come out with solutions to maximize the potential of geospatial technology. More than 52 exhibitors used the platform to showcase their products and solutions, make new contacts, and reach out to larger number of clients in both public and private sectors.

On this occasion, a report developed by Geospatial Media and Communications was inaugurated. Called *Geospatial Technology in India*, the comprehensive report traces the scope, nature and trends of the geospatial technologies in the country.

From top: A.S. Kiran Kumar (right), Chairman, ISRO, receives India Geospatial Leadership ('Making a Difference') Award from Gen V.K. Singh, Minister of State (Independent Charge) for Development of North Eastern Region;
Maj Gen Dr R Siva Kumar (Retd) (far right) receives India Geospatial Lifetime Achievement Award from Gen V.K. Singh (left) as Dr. Shailesh Nayak, former Secretary, Ministry of Earth Sciences, Government of India, looks on;
Rakesh Verma, MD & Co-Founder of MapmyIndia (far right), is conferred with the Geospatial Business Leader at India Geospatial Awards 2015



The guest list

The chief guests for the opening day and plenary sessions included Steve Berglund, CEO, Trimble; Greg Bentley, CEO, Bentley; Mladen Stojic, President, Hexagon Geospatial, USA; Dr Kumar Navulur, Senior Director, Strategic Programs, DigitalGlobe; Kshemendra Paul, Office of the Director of National Intelligence, USA; Dr VK Dadhwal, Director, National Remote Sensing Centre, India; Dr Shailesh Nayak, former Secretary, Ministry of Earth Sciences, Government of India; and Prem Jain, Chairman, AECOM, among others.

According to Berglund, India presents tremendous growth and opportunity for GIS market. He said there had been a paradigm shift in many of the application like construction, agriculture, health sectors. Emerging economies are producing opportunities for GIS.

Stojic spoke about how the map of the future is fresh; provides answers; is portable; makes sense; and is *not* a map. Meanwhile, Bentley introduced conceptioneering and Reality Modeling to the audience, and Navulur detailed on how location intelligence can be enabled with satellite technologies. Jain talked about green buildings and sustainable infrastructure initiatives. Paul emphasized on the critical role organizational partnerships and open interoperability standards play in enabling information sharing environments.

India Geospatial Awards 2015 winners announced

Organized to recognize and encourage innovations and excellence brought forward by geospatial technology developers, professionals, end users and policymakers in India, the awards were given in two categories — Leadership Awards and Excellence Awards. Gen V.K. Singh, Minister of State (Independent Charge) for Development of North Eastern Region presented the awards to the awardees.

Leadership Awards

Lifetime Achievement: **Maj Gen Dr R Siva Kumar (Retd)**

Leadership ('Making a Difference'): **A.S. Kiran Kumar, Chairman, ISRO**

Geospatial Business Leader: **Rakesh Verma, MD & Co-Founder of MapmyIndia**

Capacity Development: **Bhaskaracharya Institute for Space Applications and Geo-Informatics (BISAG), Gujarat**

Leading Geospatial State: **Rajasthan**

Excellence Awards

Application Of Geospatial Technology For Urban Planning And Smart Cities: **Dholera Special Investment Region (DSIR), Gujarat, and AECOM India**

Integration of engineering support plan with GIS during armed operations: **Indian Army**

Internet Based Dairy Geographical Information System: **National Dairy Development Board**

Application of Geospatial Technology in Governance: **Punjab Remote Sensing Centre**

BRICS working group meeting

GeoSmart India 2016 also played host to the first BRICS working group meeting on geospatial technologies (BRICS-WG-GS). The meet was jointly organized by Department of Science & Technology's NRDMS-NSDI division and International Multilateral and Regional Cooperation division along with Geospatial Media, and focused on the theme 'Geospatial Technologies for Good Governance and Decision-making'.

Watch all the video coverage from GeoSmart India 2016 on our YouTube channel: https://goo.gl/s9w9VI

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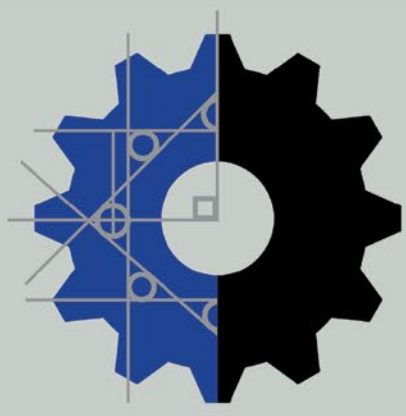

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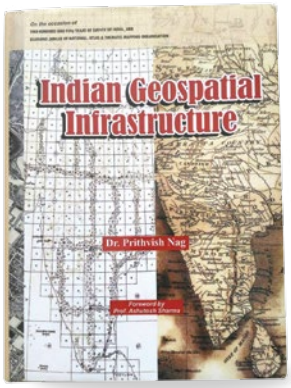
Indian Geospatial Infrastructure
A Critical Review



Author
Dr Prithvish Nag

The book Indian Geospatial Infrastructure is a good effort but the title belies the contents which are related only to Survey of India, National Atlas and Thematic Mapping Organization and other Department of Science and Technology projects

The book Indian Geospatial Infrastructure had been published on the occasion of the celebration of 250 years of Survey of India and Diamond Jubilee of National Atlas and Thematic Mapping Organization (NATMO). The author, Dr Prithvish Nag, is perhaps the best informed about both these organizations as he has served as the Surveyor General of SoI and Director NATMO for several years. This slim volume of 200 odd pages encapsulates the history of the development of a crucial geospatial technology, namely, surveying.

The book begins with a chapter on the brief history of cartography in general stretching from ancient methods to modern techniques including remote sensing and GIS and then recounts briefly the cartographic activities of SoI and NATMO. The author then delves into the development of surveying and mapping in the second chapter, beginning with a general discourse on mapping knowledge and continuing with the evolution of Survey of India and its growth till the present day and the challenges it faces. Chapter 3 continues with the transformation of Indian national mapping agencies, namely SoI and NATMO, with latest technologies and some of their achievements. However, I found the best chapters to be 4 on Datum and Map Projections, 7 on Legal Issues, 8 on Managerial Issues and 9 on Copyright Issues. Chapters 5 and 6 dwell on NRDMS and NSDI at length. The remaining chapters are on typical applications.

The book is, however, somewhat dated. It does not cover the current events like the changes in the remote sensing policy and the emergence of the National GIS; events which happened well before 2016, the publishing date. It also does not critically examine issues relating the Indian geospatial infrastructure and the manner in which these issues have been addressed or ignored. Also, since it is all about Indian efforts, it is a bit disconcerting to see the other efforts like NNRMS and GISNIC only given passing reference. Relevant activities of the Geological Survey of India, Central Groundwater Board, Central Water Commission, Department of Forestry and Environment, Department of Rural Development, National Wasteland Development Board, Ministry of Urban Development and many others have found no mention, even though these have resulted in significant additions to the Indian geospatial infrastructure.

Another glaring omission is the role played by the private industry, which has played and is playing a significant role from supply of hardware and software to development of infrastructure through projects. The mess-up over the Google Mapathon does not find mention either in policy or in copyright chapters. The role of UAVs is a hot topic but ignored in discussions on the future. Also the issue of privacy is not addressed.

Further, it lacks an index that could help the reader to quickly find topics of interest. Nevertheless, it is a good effort to educate an Indian geospatial practitioner, who is usually geographically challenged, about Indian maps and related geoid and projection issues. Apart from the historical accounts of SoI, and NATMO, NRDMS and NSDI, the book is a good compilation of legal, managerial and copyright issues which are becoming increasingly important as India tries to embrace geospatial systems in a big way.

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