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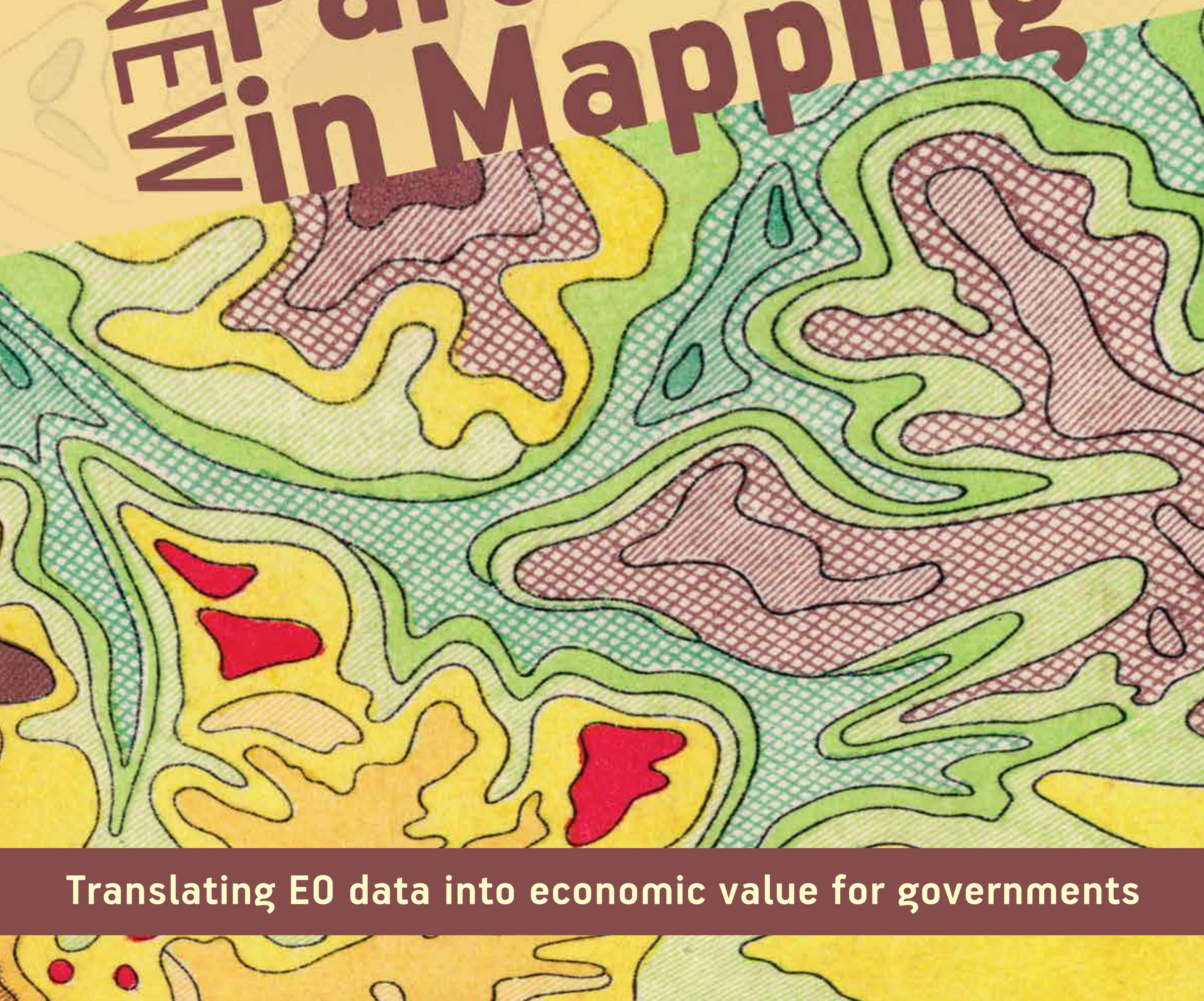
NEW Paradigm in Mapping



Translating EO data into economic value for governments

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Navigating with NaVIC

With the approval of NaVIC –India's regional navigation system

By Global Standard Body 3rd Generation Partnership Project (3GPP)

That develops protocols for mobile telephony,

Use of NaVIC is set to get a boost in India,

Potentially huge market.

Once, Telecommunications Standards Development Society, India (TSDSI) adopts these specifications as national standards,

Cellular positioning devices will begin to use the NaVIC system.

Companies can design and manufacture the NaVIC specific circuits

And researchers can develop NaVIC enabled services especially in 4G, 5G, IOT, etc.

Citizens of India await to navigate with NaVIC.

Bal Krishna, Editor
bal@mycoordinates.org

Translating Earth observation data into economic value for governments

The data and knowledge derived from EO along with new technologies and services can help countries to turn open Earth observation data into economic value

Steven Ramage
Head of External Relations, Group on Earth Observations (GEO), Switzerland

As the world's economy shifts towards a new model of growth in line with the Fourth Industrial Revolution, sustainable development solutions require large amounts of data for decision makers to effectively and efficiently manage the planet's resources. Future resource management requires that policy makers have openly available, accessible and up-to-date data and information on land use, oceans, forests, infrastructure and transportation along with services, applications and knowledge on how to manage increasingly scarce resources.

Earth observations (EO) provide insights that enable data-driven decisions, which contribute to sound economic policies. Knowledge derived from Earth observations empowers us to make better use of resources, creates new jobs and investment opportunities, spurs innovation and supports research. By highlighting the changes to our natural and built environments over time, Earth observations support better long-term investment planning and policy making for stronger economies, communities and environments.

Earlier this year, the Blockchain + AI + Human Summit – a side event of the World Economic Forum (WEF) Annual Meeting 2019 in Davos, Switzerland – explored how Earth observations can provide insights that inform evidence-based policy and decision making, visually and over time.

A recent report, Demonstrating the Value of Earth Observations, prepared in cooperation with the National Oceanic and Atmospheric Administration (NOAA), FourBridges, European Space Agency (ESA) and European Association of Remote Sensing Companies (EARSC) emphasizes the valuable link between EO data and the impact on citizens. Over 60 international experts including economists, scientists, and engineers provided inputs to this GEOValue initiative. Similarly this past summer, a workshop on Advancing the understanding and measurement of the societal benefits of Earth Observations was conducted by EARSC, FourBridges and other partners at the ESA Centre for Earth Observation in Frascati, Italy to help to define methodologies for measuring the value of EO investments. While those of us in the Earth observation community are well aware of the benefits, it is also our job to translate those benefits into value for governments and other beneficiaries.

EO data provides a wealth of information for policy makers and with open data policies, for example from Landsat and Copernicus, this data is openly and freely available around the world. If used and produced in such an open and transparent way, investments in EO can produce knock-on economic benefits for countries.

Consider some of the data coming out of the US and Australia, two countries that have made considerable investments in Earth observation infrastructures, and have committed to making those data freely available:

According to data from the U.S. Geological Survey (USGS), since 2008, the year that USGS stopped charging for the use of Landsat images, a surge of academic research was created along with users in government and industry. This has created about $2 billion in annual economic benefits, while the Landsat budget stands at about $80 million. This is just one example where investments in Earth observations data translate into economic benefits.

In Australia, the use of Earth observations, spatial information and location technologies is used in several sectors of the economy.

"Earth observations from space are one of the richest sources of information about the Earth system, and are informing decisions and activities across sectors as diverse as mining, community safety and healthcare," said Dr Trevor Dhu, A/g Branch Head, National Earth and Marine Observations Branch, Environmental Geosciences Division, Geoscience Australia.

As he explained, the country expects Earth observations to play a key role in economic growth.

"Australia's spatial industry is forecasted to generate 15,000 new jobs and contribute around $8 billion per annum to Australia's economy by 2025," said Dr Dhu.

The Australian government invested AUD $36.9 million in Digital Earth Australia (DE Australia) to provide environmental monitoring products and services to government and industry by leveraging Geoscience Australia's archive of almost four decades of satellite data, explained Dr Dhu. By mapping everything from soil and coastal erosion, crop growth, water quality and changes to cities and regions, DEA provides government, and business with the insights they need to make better decisions.

By making its data and technology openly available, DE Australia is enabling small businesses to generate new and innovative technology. This will increase the profitability and productivity of businesses in sectors such as land planning, environmental management, agriculture, and mining, bolstering profits and creating new jobs.

Australia is hosting the upcoming Group on Earth Observations (GEO) Week 2019 from November 2-9. As one of the world's largest gatherings of Earth observation practitioners and experts, the theme of the GEO Week Ministerial Summit will focus on "Earth Observations for Economic Growth." For the first time ever, a dedicated Industry Track will focus on the commercial Earth observation sector and their contributions to global decision making.

The Group on Earth Observations (GEO) is an intergovernmental partnership of hundreds of agencies from 107 member countries consisting of national government agencies and over 100 partner organizations that are committed to open data sharing of Earth observations. The resources provided by the global GEO community contribute substantially to economic decision making in far-reaching areas - from forestry and agriculture to energy and mineral resource management and many others. GEO works with member governments to help translate EO into economic value. Today, the GEO Secretariat is also working to move the needle from open data to open science and to ensure reproducibiity of results from the GEO Work Programme.

Consider some of the economic impacts of open data policies around the world:

Sustainable Supply Chains in Brazil rely on transparent and traceable satellite imagery on soy production and forestry data to ensure agricultural outputs do not contribute to deforestation practices. In 2006, the soy moratorium was informed by Earth observations data which enabled the government to make informed export decisions based on satellite data of rainforest and agricultural land-use to sustainably manage the $35 billion corn and soy industry.

The Common Agricultural Policy (CAP) in the European Union depends on a coordinated approach to improving agricultural outputs across the EU. It relies on open and shared Earth observations data including satellite data and in situ measurements to manage agricultural productivity by promoting technical progress and ensuring the optimum use of resources. The CAP budget is estimated at €50-60 billion Euro and it benefits an estimated 11 million farms in the EU and 22 million workers in the sector using open and shared Earth observations data to drive policy decisions.

In South Africa, the National Oceans and Coastal Information Management System is integral to the government's Nine Point Plan for economic growth. The Management System provides decision support tools such as vessel tracking, data on harmful algal blooms and coastal inundation. This data allows officials to understand the scope of the ocean resources and they estimate that South Africa's ocean economic potential ranges between R129 and R177bn by 2033, with between 800 000 to 1 million jobs created.

Global weather predictions rely on Earth observation data for accurate forecasting. Weather forecasts can be used to mitigate the impacts of extreme weather events on local economies and are also key to areas such as travel and transport, urban planning, pollutant monitoring, and other key areas of social development. Studies have shown that early warnings result in lower disaster response and recovery costs.

According to data from the World Bank, World Meteorological Organization and the Global Facility on Disaster Risk Reduction, it is estimated that universal access to early warning systems totals $13 billion in avoided global asset losses per year and $22 billion is avoided in global well-being losses per year. They estimate that for every dollar spent, a ratio of 3 times is saved.

These examples illustrate the short-term economic benefits made possible by Earth observations. However, the true economic value of Earth observations data is their proven and potential contributions to ensuring long term sustainability of our planet.

According to the WEF 2019 Global Risks Report, informed policy decisions are key to our sustainable future. Without insights from Earth observations, sustainable management of our planet

> EO data provides a wealth of information for policy makers and with open data policies, for example from Landsat and Copernicus, this data is openly and freely available around the world. If used and produced in such an open and transparent way, investments in EO can produce knock-on economic benefits for countries.

and ensuring ongoing availability of resources in our shared future on this planet will not be possible.

Earth observations for the growth of developing countries

Developing nations are disproportionately affected by lower levels of socioeconomic development, they suffer from poorer health outcomes, lower levels of productivity and are the ones most vulnerable to climate and disaster risks.

Earth observations are allowing developing countries to do more, and work better, in confronting challenges including air and water quality, sustainable cities, food security, disaster risk reduction, climate change and much more. In fact, Earth observations play a key role in supporting targets and indicators for the United Nations' Sustainable Development Goals (SDGs), specifically on targets related to land-use, desertification and land degradation. It has been estimated that we lack data for 68% of the SDG Indicators. Earth observations can support tracking of SDGs and compliment traditional statistical reporting in countries.

Crucial to this effort is the open and freely available data provided through the activities of the GEO Work Programme and regional GEO initiatives to support developing countries. This data is helping improve outcomes around agricultural productivity, governance and inclusive growth.

The knowledge derived from EO makes the issues we are facing clear and visible, and therefore harder to ignore. EO supports better investments in national infrastructures and institutions that support development objectives, and facilitates the tracking and measurement of results. Through GEO, all community stakeholders are encouraged to contribute to co-production of knowledge, tools and services that support the integration of Earth observations in national development processes and the strengthening of institutions.

Regional data cubes are impoving access to analysis ready data and information obtained from EO. For example, the recently launched Digital Earth Africa (DE Africa) initiative uses existing Open Data Cube technologies developed in Australia to provide rich data to decision makers across the African continent. DE Africa is envisioned as a continental-scale operational Data Cube for Africa. Taking freely available, analysis-ready satellite imagery as an input, the Data Cube will manufacture full-resolution, decision-ready products, available to one and all.

Developing countries, especially those located in Africa, are poised to benefit from advances in the digital economy and digital technologies. For example, advances in cloud computing, big data analytics and open data sharing are revealing new possibilities for developing countries to benefit from EO data. Innovations in cloud computing and analysis ready data have lowered the barrier for individuals and organizations to use Earth observations, without having to make large investments to do so.

The GEO – Amazon Web Services Earth Observation Cloud Credits Programme, launched in 2019, offers grants to national government agencies and research organizations from developing countries. These grants for cloud services help with the hosting, processing and analysis of big Earth observation data.

For example in Nepal, the International Centre for Integrated Mountain Development (ICIMOD) is using cloud computing processing for project 'South Asian drought monitoring to support agricultural advisory processes.' As a recipient of the GEO-AWS Cloud Grant, the ICIMOD programme aims to support several developing countries across the region with a harmonized system for drought management and mitigation, helping countries to save time and money in their planning and prediction efforts.

In Brazil, a project from the National Institute for Space Research (INPE), Brazilian Earth Observation Data Cube using AWS for Land Use and Cover Change, will utilize existing data cube technologies to rreate analysisready data sets from medium-resolution remote sensing images for all Brazilian territory, including images from the Earth observation satellites Landsat, CBERS and Sentinel.

In Indonesia, researchers are using cloud credits to develop a mobile tsunami warning system based on JPL's mobile Global Real-time Earthquake and Tsunami Alert (GreatAlert) prototype system and to release it as an open-source platform. This project will enable the scientific community to access NASA data and software for improvements of earthquake and tsunami modeling based on real events and aims to impact the end users, including coastal residents and beach visitors to receive early tsunami alerts.

From the standpoint of the GEO community, all countries need to take advantage of the opportunities presented by Earth observations. The data and knowledge derived from EO along with new technologies and services can help countries, and especially developing countries, to turn open Earth observation data into economic value. The current call from the GEO Secretariat is to build on the use of cloud services as the primary method for effectively mining information from satellite imagery big data to support policy, decision making and action.

New paradigm in mapping: A critique on cartography and GIS

This paper argues for a new paradigm in mapping, based on fractal or living geometry and Paretian statistics, and – more critically – on the new conception of space, conceived and developed by Christopher Alexander, that space is neither lifeless nor neutral, but a living structure capable of being more living or less living

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"Two important characteristics of maps should be noticed. A map is not the territory it represents, but, if correct, it has a similar structure to the territory, which accounts for its usefulness. If the map could be ideally correct, it would include, in a reduced scale, the map of the map; the map of the map, of the map; and so on, endlessly, a fact first noticed by Royce."
Alfred Korzybski (1933)

Abstract

As noted in the epigraph, a map was long ago seen as the map of the map, the map of the map, of the map, and so on endlessly. This recursive perspective on maps, however, has received little attention in cartography. Cartography, as a scientific discipline, is essentially founded on Euclidean geometry and Gaussian statistics, which deal with respectively regular shapes, and "more or less similar things". It is commonly accepted that geographic features are not regular and that the Earth's surface is full of fractal or scaling or living phenomena: "far more small things than large ones" at different levels of scale. This paper argues for a new paradigm in mapping, based on fractal or living geometry and Paretian statistics, and – more critically – on the new conception of space, conceived and developed by Christopher Alexander, that space is neither lifeless nor neutral, but a living structure capable of being more living or less living. The fractal geometry is not limited to Benoit Mandelbrot's framework, but towards Christopher Alexander's living geometry and based upon the third definition of fractal: *A set or pattern is fractal if the scaling of "far more small things than large ones" recurs multiple times*. Paretian statistics deals with "far more small things than large ones", so it differs fundamentally from Gaussian statistics, which deals with "more or less similar things" essentially. Under the new paradigm, I make several claims about maps and mapping: (1) Topology of geometrically coherent things – in addition to that of geometric primitives – enables us to see a scaling or fractal or living structure; (2) Under the third definition, all geographic features are fractal or living, given the right perspective and scope; (3) Exactitude is not truth – to paraphrase Henri Matisse – but the living structure is; and (4) Töpfer's law is not universal, but scaling law is. All these assertions are supported by evidence, drawn from a series of previous studies. This paper demands a monumental shift in perspective and thinking from what we have used to on the legacy of cartography and GIS.

1. Introduction

Euclidean geometry has served as the foundation of cartography, ever since human beings began to measure the magnitude of the Earth, if not even earlier (Robinson et al. 1995, Slocum et al. 2008, Anson and Ormeling 2013). We cartographers tend to see geographic features individually rather than holistically, non-recursively rather than recursively; we tend to focus on individual scales rather than on all scales or the underlying scaling hierarchy ranging from the smallest to the largest (Jiang and Brandt 2016); we tend to believe in – consciously or subconsciously – "more or less similar things", as reflected in Tobler's law (Tobler 1970), rather than "far more small things than large ones", which is formulated as scaling law (Jiang 2015a). This Euclidean geometric perspective is so stubborn that makes some maps or mapping – for example automatic map generalization – difficult or virtually impossible. A cartographic curve is traditionally viewed as a collection of more-or-less similar line segments – a non-recursive perspective. From a recursive perspective, a cartographic curve consists of "far more small bends than large ones", and small bends are embedded in large ones (Jiang and Brandt 2016). Inspired by the living geometry of Christopher Alexander (2002–2005), a cartographic curve is a coherent whole, in which nested bends constitute coherent sub-wholes at different levels of scale.

In general terms, geographic features look regular only at a local scale, but they are essentially irregular; geographic features look "more or less similar" only at one scale (Note: the scale means size rather than map scale), but there are essentially "far more small geographic features than large ones". This notion of "far more smalls than larges" recurs multiple times, indicating a scaling hierarchy of numerous smallest, a very few largest, and some in between the smallest and the largest. However, the scaling hierarchy is quite well hidden in various representations of geographic information systems (GIS), such as raster and vector (Bian 2007, Goodchild 2018). These geographic representations, based on mechanistically imposed geometric primitives of pixels, points, lines, and polygons, are unable to reveal the true scaling property of geographic features; see more discussions in Section 4.1. This mechanistic thinking is limited, for the mechanistically imposed geometric primitives do not correspond to what we perceive about geographic features (c.f. Figure 5 for an illustration). Thus with the mechanistic thinking, we cannot effectively see the fractal or living nature of geographic features. Instead we only see fragmented geometric primitives as equivalent to geographic features. I am, therefore, advocating a paradigm shift in cartography and GIS.

This paper intends to discuss with cartographers, both senior and young, on fractal geometric and Paretian statistical thinking, and – more fundamentally – on the new organic view of space: space is neither lifeless nor neutral, but a living structure capable of being more living or less living. For this purpose, I have attempted to write in an accessible manner so that both academics and practicing cartographers understand my arguments of the new paradigm in mapping. I am calling for a paradigm shift from Euclidean to fractal geometry, and from Gaussian to Paretian statistics, and – more importantly – from the mechanistic thinking of Descartes (1637, 1954) to the organic thinking of Alexander (2002–2005). In order to see scaling or fractal or living structure clearly, we must shift our mentality from geometric details of locations, sizes, and directions to overall character through topology; that is, the topology of coherent geometric entities such as rivers, cities, streets, buildings, and even tiny ornaments. The overall character refers to the underlying scaling or fractal or living structure of "far more smalls than larges".

I argue that all geographic features are fractal or scaling, given the right perspective and scope. A tree is surely fractal, but we hardly see the fractal nature if concentrating only on the scale of individual leaves (Note: I am not referring to sub-scales of the leaves, which are likely to be fractal), which tend to be "more or less similar" in terms of size and shape. Similarly, with the non-recursive perspective, one can only see fragmented pieces rather than an interconnected whole. Sierpinski (1915) carpet is fractal when seen as a whole, but we hardly see the fractal nature if viewing it fragmentally, as the disconnected squares. The same applies for traditional and vernacular building façades: they are definitely fractal, because there are "far more small things than large ones", and small things are embedded in the large ones recursively. However, we must take the recursive perspective in order to see the fractal property. I further argue that *exactitude is not truth*, to paraphrase Matisse (1947) in art, with supporting evidence from science (Borges 1946) and in particular big data (Mayer-Schonberger and Cukier 2013). I further discuss Töpfer's law (Töpfer and Pillewizer 1966) and argue why it is not universal.

The remainder of this paper is structured as follows. Section 2 reviews three definitions of fractal, especially the third one in terms of statistics and geometry. Section 3 argues for a new paradigm in mapping based on the new cosmology – a new world view or new view of space – conceived and developed by Christopher Alexander (2002–2005), that the real world is an unbroken whole, and that space is neither lifeless nor neutral, but a living structure capable of being more living or less living. Drawing on previous studies, Section 4 further elaborates on the implications of the new paradigm for maps and mapping and geospatial analysis. Section 5 concludes this paper and calls for a healthy debate on cartography and GIS.

2. Three definitions of fractal

The fractal geometry I refer to in this paper goes beyond the framework set by Benoit Mandelbrot (1982), and based on the third definition of fractal: *A set or*

Table 1: An overview of the three definitions of fractal

	About	Example	Measured by	Author
1st definition	Classic or strict fractals	Koch curve, Cantor set, Sierpinski carpet	Fractal dimension	Koch (1904), Cantor (1883), Sierpinski (1915) etc.
2nd definition	Statistical fractals	Coastlines, or natural geographic features in general	Fractal dimension	Mandelbrot (1967)
3rd definition	Head/tail breaks induced fractals	Highways, or man-made geographic features in general	Ht-index	Jiang and Yin (2014)

pattern is fractal if the scaling of "far more small things than large ones" recurs multiple times or with ht-index being at least three (Jiang and Yin 2014). This is a very relaxed definition compared to the first two, which require a power law relationship between scales and details, either strictly or statistically – that is, y = x ^ α – where α is called the power law exponent. Three definitions to be introduced represent different ways of thinking. With the first definition, scientists (e.g. Koch 1904) were puzzled by something that is not measurable, so the second definition addressed the question of how long a coastline is (Mandelbrot 1967). Instead of the how long question, the third definition attempted to ask how complex a fractal is (Jiang and Yin 2014). The most important implication for the third definition is that not only naturally occurring, but also human-made geographic features such as streets and buildings are fractal, given the right perspective and scope (c.f. Section 4.2).

The first definition is the strictest among the three and it dates back to the 19^{th} century, when there were such fractals as Cantor (1883) dust, Koch (1904) curve, and Sierpinski (1915) carpet (Table 1). Let us use the Koch curve – named after its inventor Swedish mathematician Helge Von Koch (1870–1924) – as a working example to illustrate the first definition. It requires a power law relationship or a constant ratio between two parameters, x and y, on their logarithmic scales, that is, y = x ^ -1.26, or equivalently ln(y) = -1.26 ln(x), where x and y indicate the scale and the number of segments, respectively. A segment of one unit is divided into three equal thirds, and the middle one is replaced by the two sides of an equilateral triangle (see Figure 1 for Iteration 1 or the generator). This process of division and replacement is iterative, which means that scale decreases exponentially by one-third: 1, 1/3, 1/9, and 1/27, and the number of segments increases exponentially by four times: 1, 4, 16, and 64. Mathematically, if one variable decreases exponentially and another increases exponentially, these two variables would constitute a power law relationship, i.e., y = x ^ -1.26. Shown in the power law plot, the set of points such as (1, 1), (1/3, 4), (1/9, 16), and (1/27, 64) are exactly on the trend line. This is where the problem arises. When scale is decreased to an infinite short, the length of the curve would become infinitely long. This is the so-called conundrum of length (Richardson 1961, Perkal 1966), which puzzled scientists for over 100 years until the French mathematician Benoit Mandelbrot (1967, 1982) established fractal geometry. Under the framework of Euclidean geometry, anything should be measurable, no matter how big or small it is. In fact, this is a limitation of Euclidean geometry.

The second definition is less strict or more relaxed than the first one. Mandelbrot (1967) noticed that the first definition of fractal is too rigorous for the Koch curve to be a meaningful model of the real world. As a matter of fact, there is no need for scale to decrease by exactly one-third or to have the number of segments to increase by exactly four times, to retain the power law relationship. In other words, with a decrease of scale of approximately one-third and an increase in the number of segments of approximately four times, the power law relationship still holds, not exactly but only approximately or statistically (Figure 1). On the power law plot, a set of points, such as ($1 \pm e_1$, $1 \pm d_1$), ($1/3 \pm e_2$, $4 \pm d_2$), ($1/9 \pm e_3$, $16 \pm d_3$), and ($1/27 \pm e_4$, $64 \pm d_4$) (where e_i and d_i indicate some very small epsilons or deviations), are around the trend line rather than on the trend line as in the first definition (Ma and Jiang 2018). The resulting curves look very natural, such as clouds, city skylines, and coastlines, dramatically different from the rigorous Koch curve. This shift from the first to second definition of fractal is probably another example for supporting the statement that exactitude is not truth in science (see further details in Section 4.3), because the second is more relaxed or less rigorous than the first.

The third definition is further less strict or more relaxed than the first two. Neither Koch curves nor coastlines are measurable, and their lengths depend on the measuring scale; the shorter the measuring scale, the longer the curves. For complex curves like coastlines, what matters is not how long they are, but how complex they are. "How

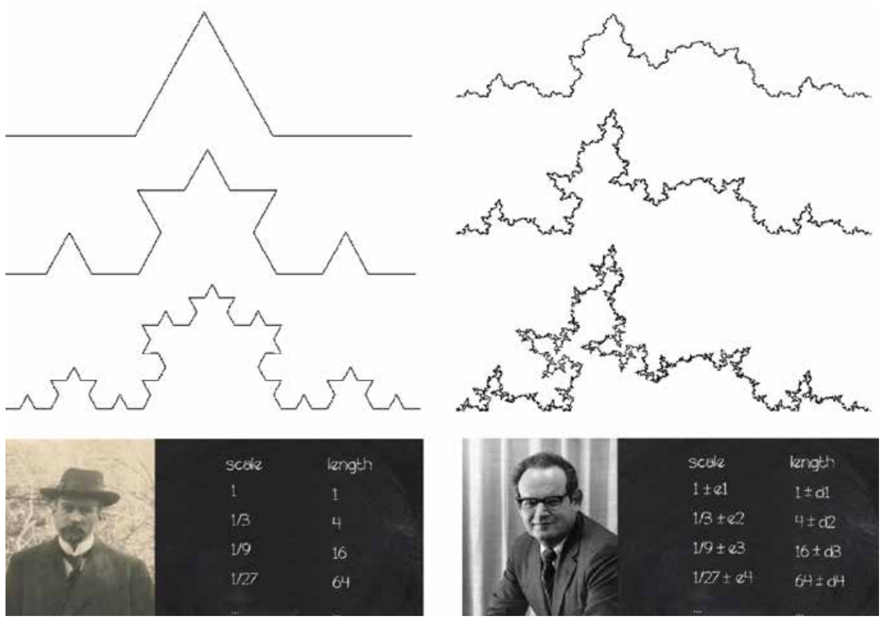

Figure 1: The first two definitions of fractal
(Note: The first definition is too rigorous, requiring a very strict power law relationship between scale and length, while the second definition is less rigorous and more statistical. In other words, the scale decreases not strictly by 1/3, but by approximately 1/3 with a small epsilon; the number of segments or length increase not exactly four times, but approximately four times with a small deviation. The two portraits from left to right are Helge von Koch (1870–1924) and Benoit Mandelbrot (1924–2010). Sources: Von Koch from "Portrait of Nils Fabian Helge von Koch" (n.d.) and Mandelbrot from at IBM (n.d.))

long" is an unanswerable question, the one that concerns Euclidean geometry or simple science in general, whereas "how complex" is an answerable question that concerns fractal geometry or complexity science in general (Jiang and Ma 2018). The first two definitions are top-down in nature; for example, given a line segment of one unit, and the generator, a fractal curve is generated iteratively. In other words, the generator is applied iteratively again and again, at increasingly fine scales. Eventually, very convoluted and very complex curves are generated. In contrast to the first two definitions, the third definition is not constrained by the power law relationship. Instead, it examines, given a set or pattern, whether the scaling of "far more small things than large ones" recurs multiple times (Jiang and Yin 2014). These multiple times or the ht-index would answer the "how complex" question about the set or pattern. The new paradigm is actually to confront or to address the issue of "how complex"; more specifically, maps and mapping must reflect the underling complex, scaling, fractal, or living structure of the Earth's surface.

To further illustrate the third definition, let us examine the 100 numbers that exactly and strictly follow Zipf's law (1949): 1, 1/2, 1/3, …, and 1/100. The average of the 100 numbers is 0.05, which partitions these numbers into two parts: the first 19 numbers (about 20 percent, all greater than the average, called the head), and the last 81 numbers (about 80 percent, all less than the average, called the tail). The average of the first 19 numbers is 0.19, which again partitions the 19 numbers into two parts: the first five (25 percent, all greater than the second average, called the head); and the remaining 14 (75 percent, all less than the second average, called the tail). The average of first five numbers is 0.46, which partitions the five numbers into two parts: the first two (40 percent in the head) and the remaining three (60 percent in the tail). This recursive process is called head/tail breaks (Jiang 2013a, 2015c). The head/tail breaks process continues recursively or iteratively three times or the scaling of "far more small numbers than large ones" recurs three times, implying four hierarchical levels for these 100 numbers; that is, [0.01, 0.05], (0.05, 0.19], (0.19, 0.46], (0.46, 1]. The number of recurrent times is called the ht-index – an alternative index to fractal dimension for characterizing the complexity of fractals or geographic features in particular (Jiang and Yin 2014). The notion of "far more small things than large ones" is also well reflected in the four hierarchical levels. There are 81, 14, 3, and 2 numbers, respective to the four levels from the lowest to the highest. The ratio of upper class to lower class is always a minority to a majority; that is, 14/81, 3/14, and 2/3, which reflects the underlying scaling hierarchy of "far more smalls than larges".

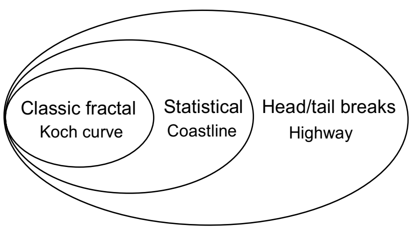

Figure 2: Three definitions of fractal and their implications
(Note: The three definitions are respectively referred to as classic fractal, statistical fractal, and head/tail breaks induced fractal. The second definition is more relaxed than the first, while the third is even more relaxed than the second. It is important to note that a coastline is not fractal under the first definition, and a highway is not fractal under the second definition yet both are fractal respectively under the second and third definition.)

The notion of "far more smalls than larges" must be comprehended not only statistically, but also in terms of the underlying geometry (or spatial configuration to be more precise). Assuming the 100 numbers are 100 city sizes, their distribution over a region of space follows the scaling hierarchy, characterized by the central place theory (CPT) (Christaller 1933, 1966, Chen and Zhou 2006). The CPT model implies that large cities are surrounded or supported by medium-sized cities, which are further surrounded or supported recursively by small cities, forming a scaling hierarchy. This geometric aspect indicates that cities are adapted each other or that nearby cities are "more or less similar". This adaptation can also be seen from Tobler's law (1970), which states that nearby things (or cities in particular) tend to be "more or less similar". Therefore, the third definition of fractal involves both statistical and geometric aspects. This definition implies that not only coastlines but also highways are fractal (Figure 2). As mentioned at the outset of this paper, a cartographic curve should be more correctly viewed as a collection of recursively defined bends, and recurrent scaling of "far more small bends than large ones". However, highways are not fractal under the first two definitions, since they tend to be smooth or regular. The third definition of fractal, which is more towards living geometry (Alexander 2002–2005), provides a theoretical basis to support a new paradigm in cartography.

3. The new paradigm in cartography

A new paradigm occurs in science when the basic concepts and experimental practices of a scientific discipline undergo a drastic revision. More than just replacing techniques, a paradigm shift means an entirely new way of looking at the real world (Kuhn 1970). The new paradigm in cartography is essentially built on the new cosmology – the conception of physical reality – conceived by Christopher Alexander through his life's work: *The Nature of Order: An essay on the art of building and the nature of the universe* (Alexander 2002–2005), a four-volume opus on art, science, nature, and beauty (c.f. Alexander 2003 for a short summary of the masterful work for a scientific audience.). Under the new cosmology, space is unlike what we were told under the mechanistic framework (Descartes 1637, 1954) as being lifeless or neutral, but a living structure capable of being more living or less living. For example, the Koch curves are living structure; those in the high iterations are more living than those in the low iterations; or equivalently, those in the low iterations are less living than those in the high iterations. This new organic world view or new cosmology (Alexander 2002–2005, Book 1, p. 96) is built directly on the wholeness that is defined as follows:

"*I propose a view of physical reality which is dominated by the existence of this one particular structure, W, the wholeness. In any given region of space, some subregions have higher intensity as centers, others have less. Many subregions have weak intensity or none at all. The overall configuration of the nested centers, together with their relative intensities, comprise a single structure. I define this structure as 'the' wholeness of that region.*"

The wholeness is a recursive structure that is defined mathematically, and exists physically in nature and in what we build and make (Alexander 2002–2005, Jiang 2015d, 2016, 2019b). The recursive structure recurs at different levels of scale in the deep; it is so deep that "*each time it occurred, it took a different form, and was yet, nevertheless always the same*" (Alexander 2006). Under the new cosmology or the world picture, the Earth's surface is considered to be an unbroken whole. A map eventually reflects the truth of the wholeness of the Earth's surface or part of it. Thus, the truth, or capturing the truth, should be the essence of all mapping activities. Given the circumstance, quality of maps is a matter of fact rather than personal preferences or opinions, as commonly conceived.

The above definition of wholeness can be simply rephrased as the scaling hierarchy of "far more smalls than larges". Space or geographic space in particular is neither lifeless nor neutral, but a living structure. When I say it is neither lifeless nor neutral, I am not saying that geographic space is not dynamic along the time dimension. Instead, I am saying that at any instant in time, geographic space is not neutral and it has the capacity of being more living or less living. We need to adopt a holistic view in order to see the capacity of geographic space. The scaling hierarchy cannot be effectively characterized by Euclidean geometry, but it can by fractal geometry (Mandelbrot 1983), particularly the fractal geometry – or living geometry – under the third definition: *A set or pattern is fractal if the scaling of "far more small things than large ones" recurs multiple times with the ht-index being at least three* (Jiang and Yin 2014). It is important to realize the paradigm shift from Descartes' mechanistic world picture to Alexander's organic conception of the physical world (Figure 3).

The living geometry of Alexander (2002–2005) is more profound than the fractal geometry of Mandelbrot (1982) for characterizing the Earth's surface.

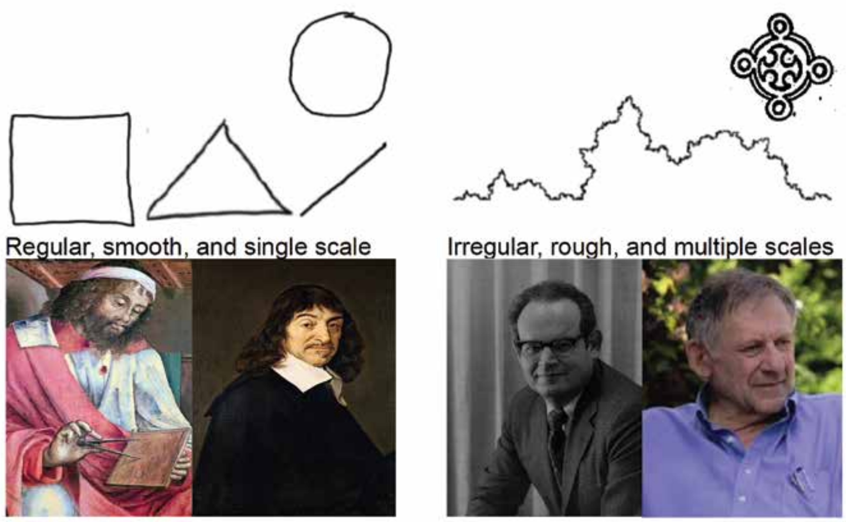

Figure 3: (Color online) Paradigm shift from Euclidean geometry to fractal or living geometry, and more importantly from Descartes' mechanistic worldview to Alexander's organic worldview (Note: The four portraits are, from left to right, of Euclid (300 BC), René Descartes (1596–1650), Benoit Mandelbrot (1924–2010), and Christopher Alexander (1936–). Sources: Alexander (2002–05) and Center for Environmental Structure; Hals (c. 1649–1700); Mehaffy (2016) via CC BY-SA 4.0; van Gent (c. 1474).)

On the one hand, the Earth's surface is a whole and it is part of a larger whole, and so on endlessly towards the entire universe. On the other hand, the Earth's surface contains countries, which further contain cities, streets, and buildings, down to the architectural scale of millimeters (e.g., to see the living structure of an ornament). The wholeness of the Earth's surface is what the new paradigm is largely based on, and it is what maps attempt to depict. To this point, I wish to correct a statement I made in the early 1990s: visualization as the core of cartography. No, visualization cannot be the core of cartography, and it is just appearance. The core of cartography is the deep structure of the wholeness, or the fractal or scaling or living structure of geographic space. Maps and mapping, such as visualization, symbolization, map generalization, and even cognitive mapping, should reflect the wholeness or the scaling hierarchy of "far more smalls than larges".

In addition to the new cosmology, emerging geospatial big data adds another incentive for the new paradigm in cartography. Big data differs fundamentally from small data in terms of three data characteristics (Mayer-Schonberger and Cukier 2013, Jiang and Thill 2015). First, big data is considered to be all rather than samples. Second, big data are accurately measured at a very high resolution, while small data are at a low resolution or roughly estimated. Third, big data are defined at the individual scale rather than aggregated as small data. These three characteristics imply that big data are better than small data in reflecting the wholeness of the Earth's surface, which tends to be very heterogeneous and diverse. The heterogeneity and diversity cannot be well seen in raster and vector representations of GIS, since they are based on geometric primitives of pixels, points, lines, and polygons (Bian 2007, Goodchild 2018), which tend to be "more or less similar" rather than "far more smalls than larges"; see Figure 5 for an illustration. Instead, we should take spatially or geometrically coherent entities as basic units, e.g., named or natural streets as shown in Figure 5, and assess how they constitute a coherent

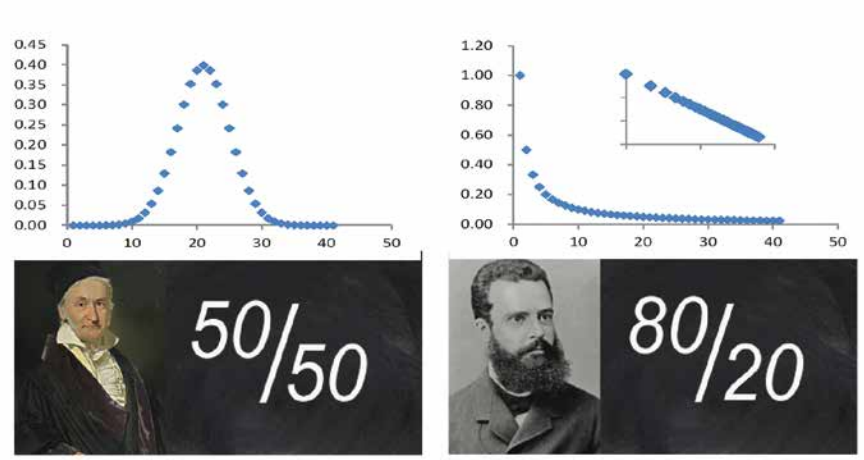

Figure 4: (Color online) Paradigm shift from Gaussian statistics to Paretian statistics (Note: The bell curve is shown in the histogram plot, while the long tail curve, with the inset of log-log plot, is in the rank-size plot, although it would look like a long tail as well in the histogram plot. The two portraits from left to right are the German mathematician Carl Friedrich Gauss (1777–1855), and the Italian economist Vilfredo Pareto (1848–1923). Sources: Gauss from Jensen (1840) and Pareto from "Vilfredo Pareto" (c. 1870))

whole, from which sub-wholes can be identified. A coherent whole emerges from a holistic perspective, or more truly from its spatial configuration point of view.

This new paradigm requires shifting our ways of thinking, not only geometrically (Figure 3) but also statistically (Figure 4). The third definition of fractal is based on the notion of "far more smalls than larges", indicating actually a Paretian distribution. It is not the bell curve shown in histogram, but a long tail in the rank-size plot (Zipf 1949). This long-tailed distribution can be shown to have hierarchical levels through head/tail breaks (Jiang 2013a, 2015c). Under the new paradigm, different types of mapping can be considered the head/tail breaks process for thematic mapping, for map generalization, for cognitive mapping, and even for perception of beauty (Jiang 2013a, 2013b, Jiang et al. 2013, Jiang and Sui 2014, Jiang 2015b). This beauty is a new kind of beauty that exists in deep structure – structural beauty – out of the deep structure of wholeness (Jiang and Sui 2014). The new paradigm implies that cartography should go beyond conventional GIS representations towards topological representations that enable us to see the underlying scaling or fractal or living structure of the wholeness of the Earth's surface. I will further discuss this implication and others in the next section.

4. Implications of the new paradigm in cartography

The new paradigm has some deep implications for cartography and GIS and for mapping and geospatial analysis in particular. Under the new paradigm, a map would become the truth of the wholeness of the Earth's surface, and mapping processes of various kinds should be largely guided by the scaling law (Jiang 2013b, Jiang 2015a, 2015b). In general terms, cartography is a science – the one based on the complexity science, e.g., fractals, scaling hierarchy, and living structure, just to mention a few examples. Under the new paradigm, conventional mathematics such as Euclidean geometry and Gaussian statistics remain valid for measuring and analysing geographic objects with respect to Tobler's law or to the notion of "more or less similar things", but are unlikely to be of much use for developing new insights with respect to spatial heterogeneity or scaling law.

4.1 Topology matters for seeing a scaling or fractal or living structure

The foundation of the new paradigm is the organic world picture, from which geographic space – or space in general – is viewed as a scaling or fractal or living structure. In order to see this living structure clearly, we must adopt a topological perspective – the topological relationship among geometrically coherent entities such as rivers, lakes, streets, and buildings. Conventional GIS are essentially based on a geometric perspective, focusing on geometric details of locations, sizes, and directions, and based on geometric primitives of pixels, points, lines, and polygons (Bian 2007, Goodchild 2018). In this regard, a street network is a very good example. A street network is conventionally seen as a graph of street nodes or street segments (Figure 5a). Structurally speaking, the graph to the left is very homogeneous with

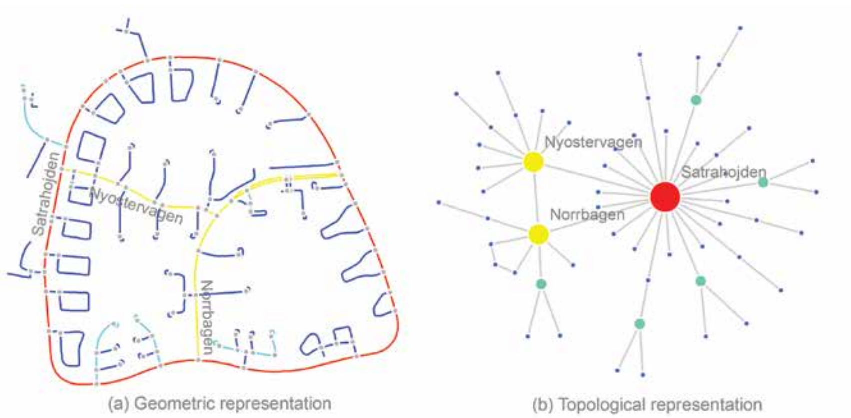

Figure 5: (Color online) Illustration of geometric and topological representations (Note: Geometric representation (a), due to geometric details such as locations, length, and directions, must be transformed into the topological representation (b) in order to see clearly the scaling property of "far more less connected than well connected things". The topological representation bears no geometric details at all. Source: Adapted from Jiang and Claramunt (2004). Copyright © 2004 by Pion. Reprinted with permission by SAGE Publications, Ltd.)

characteristic scales, since each node or street segment has "more or less similar" number of connections. Three or four can be said to be a characteristic scale of the node's connectivity; all segments have "more or less similar length", which can be said to be another characteristic scale. Traditional mathematical description and quantitative analyses are essentially based on characteristic scales.

In fact, the street network can be more truly seen as a graph of individual streets, defined, for example, by unique names. This is the topological perspective, with which we can see "far more short streets than long ones" geometrically, or "far more less-connected streets than well-connected ones" topologically. Thus, streets constitute a fractal or living structure. It should be noted that not only streets but also street blocks – the space between all streets – are fractal, since they involve "far more small blocks than large ones" (Jiang and Liu 2012). This is in line with the notion that if a pattern or set is fractal, and its complement set tends to be also fractal (Chen 2017).

The transformation from the geometric representation to the topological representation ignores the geometric details. This is because an entire street has been abstracted as one node and, more importantly, this node has no geometric information at all except its topological information such as degrees of connectivity. Many researchers (e.g., Ratti 2004) mistakenly argued that the topological representation suffers from the loss of geometric information, so it is of less use than the geometric representation. This is indeed an extremely biased, prejudiced, and blinkered view. In fact, it is exactly through the ignorance (rather than loss) of geometric information that the topological representation gains penetrating insights into the underlying scaling structure of "far more less-connected streets than well-connected ones". Geometrically, a street network is not fractal, but topologically it is. The topological representation is considered to be the first and foremost, while the geometric one is just secondary. In other words, we don't give up the geometric representation entirely, and we only give up our devotion to it, since there is something more important – the topology – than the geometry.

4.2 All geographic features are fractal or living

Under the third definition, all geographic features are fractal or living, given the right perspective and scope. We have already seen in Section 4.1 that topology among meaningful geographic features is the right perspective for seeing the fractal or living structure of a street network. As for the scope, it is usually the case that bigger is better for seeing fractal or living. For example, a country is better than a city to see fractal, a city is better than a building, a building is better than a façade, and a façade is better than an ornament. However, as a matter of fact, fractal or living structure can be seen at different levels of scale. These examples can be extended to biology. A human body is better than an organ to see fractal, an organ is better than a tissue, and a tissue is better than a cell. In summary, the larger the scope, the more heterogeneous or more diverse the things are.

Given that all geographic features are fractal, we must adopt the head/tail breaks (Jiang 2013a, 2015c, Lin 2013) for classification and visualization rather than the commonly used the natural breaks or k-means or other classifications (Jenks 1967). For example, any digital elevation model (DEM) involves "far more low elevations than high ones". Current color rendering for DEM unconsciously exaggerates high elevations (Figure 6, Panel (a)), so it distorts – rather than reflects – the underlying fractal or living structure. Using the head/tail breaks, the DEM should have rendered as in Panel (b). Panels (a) and (b) look very different, but Panel (b) reflects well the underlying scaling or fractal or living structure of "far more low elevations than high ones. This difference can be seen clearly in the two corresponding histograms in the figure, with one showing a Gaussian-like distribution, and the other a long tail distribution.

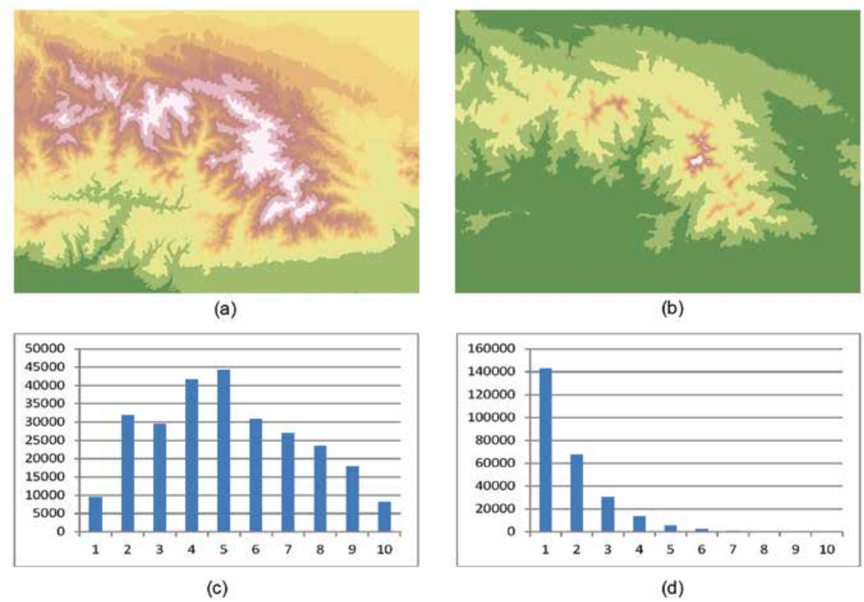

Figure 6: (Color online) Different color rendering of the same DEM (Note: Color rendering of the DEM based on natural breaks (a), on head/tail breaks (b), and their corresponding histograms (c), and (d).)

4.3 Exactitude is not truth

The title of the subheading is borrowed from the artist Henri Matisse (1947), who made some very cogent statements about his art. Matisse (1947, p. 117) noted that the overall character of a human face does not depend on *"the exact copying of natural forms, nor on the patient assembling of exact details, but on the*

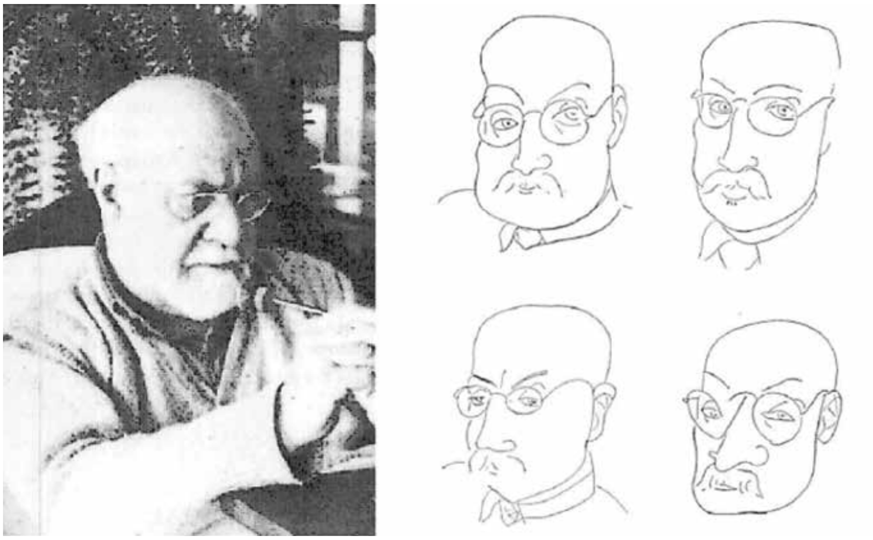

Figure 7: A photo of Henri Matisse and his four self-portraits (Note: The local details in each portrait are different, but in each of them we see the unmistakable face and character of Henri Matisse (1869–1954) – the wholeness. The wholeness of the face can be summarized as such: the bald head, with the eyes spreading concentrating downward to the mouth, and with the low parts such as mustache and jaw spreading outward. Source: Photo of Henri Matisse by Hélène Adant; four self-portraits from Matisse (1948), collection of Madame Marguerite Duthuit.)

profound feeling of the artist before the objects which he has chosen, on which his attention is focused and the spirit of which he has penetrated". Figure 7 illustrates the scene while Matisse was drawing his four self-portraits, as seen in a mirror. These four portraits differ from each other in terms of local details of the nose, chin, and eyes, yet they all look unmistakably like the face and character of Henri Matisse.

The artist argued that everything has an inherent truth that must be distinguished from its surface appearance, and this is the only truth that matters. He noticed that it is essentially truth of an object that makes a drawing or painting successful. Christopher Alexander (2002–2005) claimed that the truth is what he termed the wholeness. The wholeness exists physically in space and matter at different levels of scale, and reflects in our minds and cognition psychologically. More importantly, the wholeness is essentially a recursive structure that can be mathematically defined (Alexander 2002–2005, Jiang 2015d, 2016, 2019b).

Contrary to the assertion that exactitude is not truth, our desire for exactitude in GIS and cartography has become higher and higher. Cartographers or GIS experts in general are fond of high-resolution imagery and high-quality data in maps or GIS databases. This situation is understandable given that cartography is essentially founded on Euclidean geometry, and its initial goal was to depict the underlying structures or patterns of geographic space through scientific abstraction. Such a depiction requires high exactitude in terms of locations, sizes, and directions. In this regard, many different map projections were developed for different purposes of measurement and navigation (Yang et al. 1999). All of these achievements constitute the legacy of cartography (Bian 2007, Goodchild 2018), and have been well retained in GIS.

Cartography has been facing an important change from data collection to knowledge discovery. The past six decades of GIS history have experienced two major distinct phases of transformation: the transformation from data to information, and the transformation from information to knowledge. The former phase concerns data collection – transforming raw data into computerized information, whereas the latter is more interested in how to obtain useful information or knowledge for various spatial planning and decision making. The Euclidean geometric paradigm works well in the first phase, but it has critical limitations in the second phase. Back to Figure 7 again, the photo has the highest data quality – similar to the person in appearance, whereas the four portraits capture the highest data or personal character – similar to the person in character. The difference between similar to the person in appearance and in character is what underlies the notion of *"exactitude is not truth"*.

The issue of exactitude or overall data character has been discussed not only in art, but also in science. The Argentine writer Jorge Luis Borges (1946) wrote a one-paragraph story entitled *"On exactitude in science"*. The story, styled as an extract from a historic travel book dating on 1658 by the fictitious author Suarez Miranda, praised the value of abstraction or reduced scales of maps instead of maps of 1:1 scale. Maps of 1:1 scale are useless due to their lack of abstraction or generalization. Privileging more data of less exactitude opens new ways for big-data analytics: "*We don't give up on exactitude entirely; we only give up our devotion to it. What we lose in accuracy at the micro level we gain in insight at the macro level*" (Mayer-Schonberger and Cukier 2013, p. 13–14). The topological representation as discussed in Section 4.1 provides another good example regarding the fact that exactitude is not truth. Geometric details actually prevent us from seeing the truth – the underling scaling or fractal or living structure.

4.4 Töpfer's law is not universal, while scaling law is

Töpfer's law, also called the principle of section or radical law (Töpfer and Pillewizer 1966), provides a guideline for how many map objects should be selected or retained from the source map to the derived map. It is an empirical law, developed through counting the number of map objects in both the source and derived maps. This way of establishing the empirical law was justified at the paper map ages, when maps were mainly produced by human cartographers. However, the law was established through individual map sheets, which are artificially and mechanistically determined. Each of these determined map sheets is not a whole or sub-whole. A whole is referred to something natural or organic rather than something mechanical or artificial. For example, the Earth's surface is a whole, and a continent is a sub-whole; if a country is referred to as a whole, then its cities are sub-wholes; if a human body is a whole, then the heart or brain is a sub-whole.

Many natural objects like mountains, rivers and streets may stretch across several map sheets, and are not constrained to any one of them. Therefore, one cannot effectively count the number of objects. Some objects, like settlements or buildings, are countable, but belong to individual clusters, which cannot be effectively detected or counted in map sheets. In this regard, it would be reasonable to take a country as a whole, and its individual cities as sub-wholes, and so on. Or, if possible, take the entire world as a whole, and individual countries and cities as sub-wholes, and sub-wholes of the sub-wholes. All in all, the topological perspective rather than ordinary geometric perspective, as discussed in Section 4.1, helps us to see whole or sub-wholes. Scaling law is essentially built on this holistic view of space, and the notion of "far more smalls than larges" recurs at different levels of scale. Therefore, scaling law is universal, while Töpfer's law is not.

There are two basic functions of maps: for reading detailed individual information and for illustrating overall scaling patterns. For the reading function, maps are presented conventionally with a detailed map legend, map scale, and a compass. For the function of showing scaling patterns, map elements such as legend, scale and compass are unnecessary or less important (e.g., Figure 5b and 6b). The latter function is in line with fractal geometry focusing on patterns rather than individuals.

Cartography is a true science. I therefore suggest change the wording in the definition of cartography from "*the art, science and technology of making maps* ..." (Meynen 1973) to "*the science, art, and technology of making maps* ...". First and foremost, cartography is a science, and the art is for the sake of science, to paraphrase

Mandelbrot (1989). The art or the artistic aspect arises from the underlying scaling or fractal or living structure rather than something subjective or idiosyncratic (Griffin 2017). The fractal or living structure can evoke a sense of beauty – structural beauty that can be measured quantitatively, as well as sensed by human beings (Jiang and Sui 2014, Jiang 2015d, Wu 2015, Rofé 2016). A beautiful map must reflect the underlying living structure, which accounts for a majority of beauty, while aspects of surface beauty such as colour and design account for a minority.

5. Conclusion

Arguing for a new paradigm in mapping, this paper provides a critical analysis of the state of the art of cartography and GIS: its stubborn Euclidean geometric and Gaussian statistical thinking, and – more fundamentally – its deadly mechanistic thinking, as reflected in many GIS representations such as raster and vector. This new paradigm is established on the new organic cosmology (Alexander 2002–2005) that the universe is a coherent unbroken whole, and space is neither lifeless nor neutral, but a living structure capable of being more living or less living. Affected by modernism, postmodernism, and deconstructionism, so called fashionable nonsense (Sokal and Bricmont 1998), a map is considered not to be the truth. Contrary to this claim, I argue that a map, if correct, is essentially about the truth of the wholeness of geographic space – the essence of the argument for the new paradigm – and quality of maps is a matter of fact rather than that of opinion. I call for a paradigm shift, from Euclidean geometry to fractal geometry, and from Gaussian statistics to Paretian statistics, and – more importantly – from the mechanistic thinking of Descartes (1637, 1954) to the organic thinking of Alexander (2002–2005). I have presented three definitions of fractal and discussed how one definition gets relaxed – actually beyond – one after another, yet open new horizons to see our surrounding things insightfully. The third definition is unique in the sense that it enables us to see things organically rather than mechanistically. The new paradigm may raise discomfort in the profession, but, it nevertheless opens new ways of thinking that are highly challenging to the academic establishment of cartography and GIS.

The new paradigm has some profound implications on cartography and GIS, and for mapping practices and geospatial analysis in particular. It implies that mapping, including cognitive mapping, can be considered to be a head/tail breaks process (Jiang 2013b). It implies that the topological perspective rather than the perspective focusing on geometric details enable us to see the scaling or fractal or living structure of the Earth's surface or its sub-wholes. It implies that all geographic features are fractal under the new, relaxed third definition of fractal. It implies that the wholeness of the earth's surface relies little on geometric details, but on the overall character – the very notion of "far more smalls than larges". It implies that a map is the truth of the wholeness of the Earth's surface, and cartography is a true science. I hope that this paper can help promote healthy debates in departments of cartography and GIS, and in the cartographic community as a whole, about the legacy and future of cartography and GIS.

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Note by the author

Under the new paradigm, we have developed a fully automatic solution to map generalization (Jiang 2018). This solution starts from a single largest-scale database (e.g., 1:1K). All subsequent small-scale maps or databases can be automatically derived. This automatic process is determined by the data, so called data speak for itself. On the other hand, it is possible to integrate the user's requirements to provide customized results. The small scales include not only primary scales, such as 1:2K, 1:4K, 1:8K, ..., 1:4M, and conventional discrete scales, such as 1:2.5K, 1:5K, 1:10K, ..., 1:4M, but also any arbitrary scales, such as 1:2.345K, and 1:9.843K. In other words, this solution is able to produce maps or databases of continuous map scales, from which we choose over 10 scales for comparing our results (to your right screen) with those of OpenStreetMap (to your left screen) of Sweden as a case study of MapGEN: http://lifegis.hig.se/Sweden/

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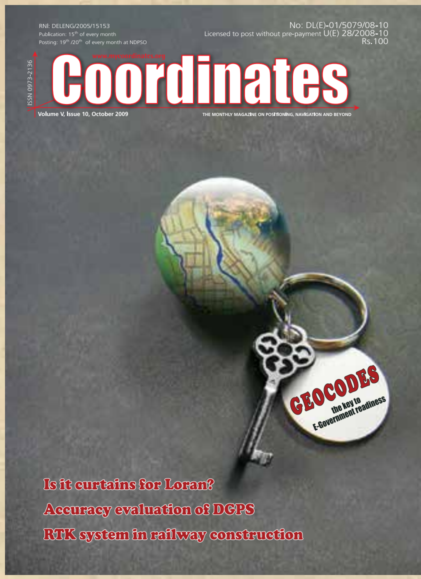
In Coordinates

10 years before...



mycoordinates.org/vol-5-issue-10-October-09

Is it curtains for Loran?

Dr Sally Basker
Director of Research & Radionavigation General Lighthouse Authorities of the United Kingdom & Ireland

From an international perspective, this may look rather confusing. However, at the time of writing, the World awaits the US Congress' decision on Loran and there is one key question to be answered: if the US decides to close Loran, will the rest of the World keep going with Loran?

This question has never, to my knowledge, been put formally to the 14 other nations that provide Loran services. However, I suspect that the majority including France, Japan, Norway, the Peoples Republic of China, the Russian Federation, Saudi Arabia, South Korea and the United Kingdom may see real benefit in system diversity and decide to keep Loran and transition to eLoran.

So, is it curtains for Loran? I don't think so but there will be a process of realignment if the US decides to close Loran

Application of RTK system in railway constructions

Haitao Xu
Senior technical engineer Beijing UniStrong Science & Technology Co,. Ltd., China

The design of railway is quite simple and fast. Railway-design software is quite advanced when designing a railway. For example to design a 40km long railway line, we only need the coordinates of intersection, distance between points of intersection, easement curve length, circular curve length and pile mileage. The main work is to arrange these elements in certain order and build a road fi le, and could be fi nished in 2 minutes.

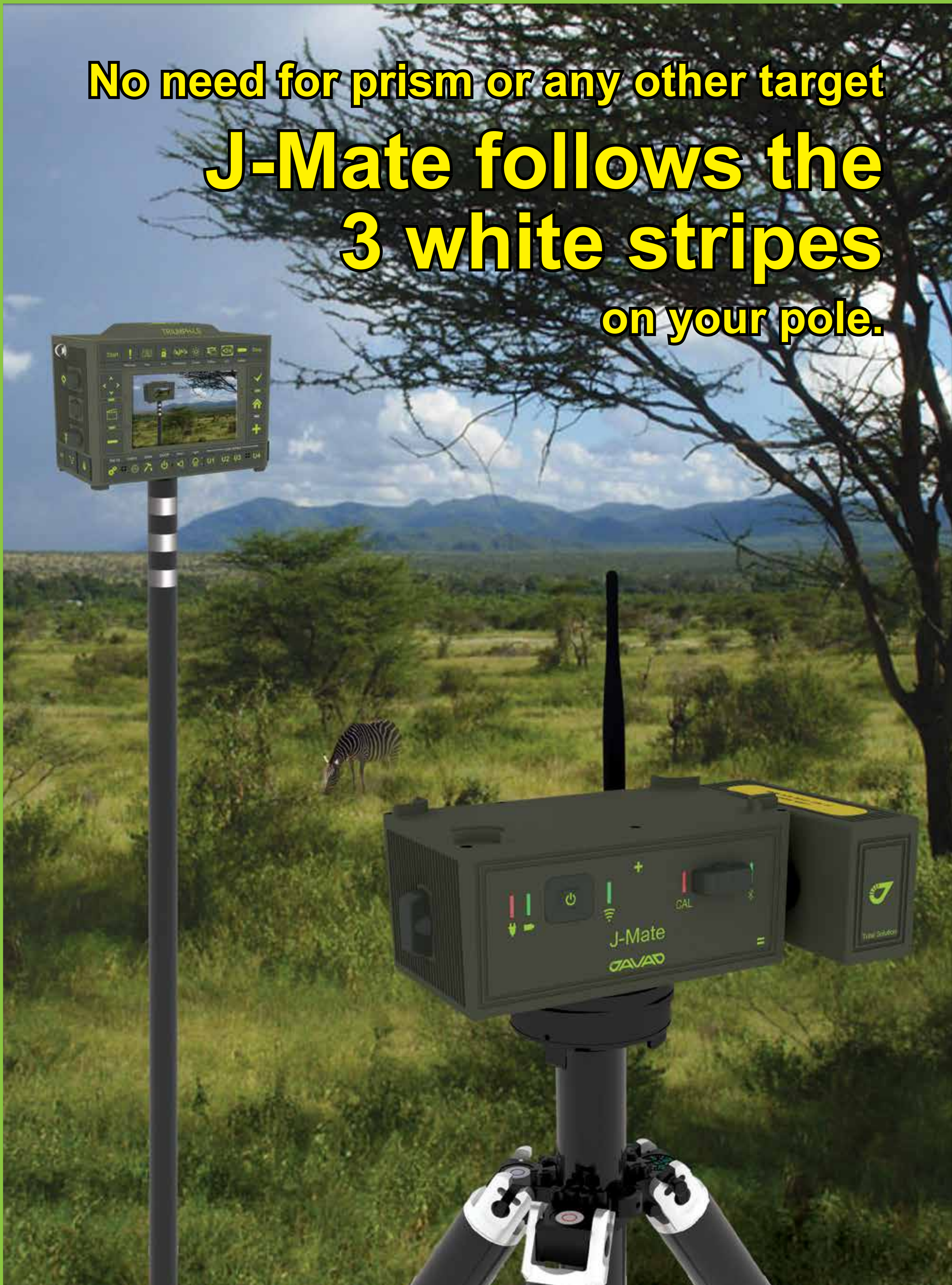
User-defi ned feature function. The function of user-defi ned features makes the inside and outside work much simpler. When surveying the profi le, if there is some topography point (such as the scarp), one needs to record the name and attributes of this point in a notebook, and then input this points details into the computer once back in the offi ce. But, with Railway-design software, the engineer can input attributes directly in the fi eld and save time.

Geocodes -the key to e-Government readiness

Peter Holland, Abbas Rajabifard and Ian Williamson
Centre for SDIs and Land Administration, Department of Geomatics, The University of Melbourne, Australia

A basic requirement for effective spatial enablement is the availability of geocodes. A geocode normally takes the form of a geographical coordinate, that is, the latitude, longitude and (sometimes) height of a point. Geocodes derived from cadastral and land administration systems are ideal for the purposes of spatial enablement because the source databases of land parcels and road corridors, street addresses and interests in land have integrity, are authoritative, are kept upto- date and are linked to a map base and a country's geodetic reference system.

Geocoded street addresses are perhaps the most useful derivative of cadastral and land administration systems in terms of Spatial Enablement of Government because street addresses are one of the most common elements in government databases.



www.javad.com

Front

Adam Plumley, PLS

I probably won't be carrying a sh*t stick with me anymore. Notice the red dot on top of the pipe.

FL

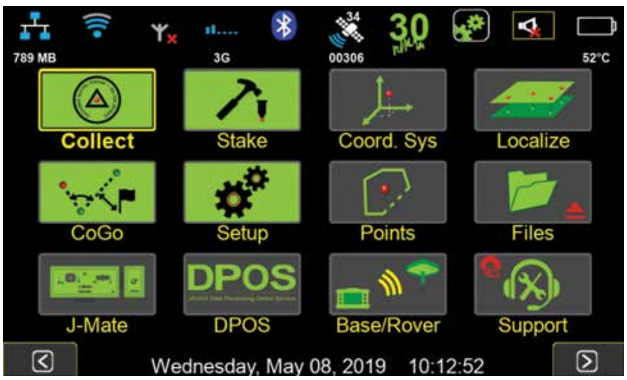
Introduction to J-Mate

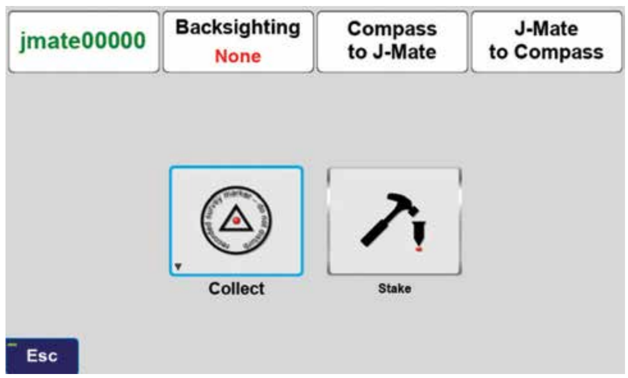
Let's set the record straight: J-Mate is not a total-station. **J-Mate and TRIUMPH-LS together** make the **"Total Solution"** which is a combination of GNSS, encoder and laser range measurements that **together do a lot more than a total station**. For long distances you use GNSS and for short distances (maximum of 100 meters) you use the J-Mate along with the TRIUMPH-LS. Together they provide RTK level accuracy (few centimeters) in ranges **from zero to infinity**.

As with the TRIUMPH-LS, with the J-Mate we also provide software improvement updates regularly and free of charge. Download the J-Mate update in your TRIUMPH-LS and then inject it to the J-Mate. The J-Mate SSID will be in this format JMatexxx, where xxx is your J-Mate's serial number. After a Wi-Fi connection is established, click the J-Mate icon and then click Setup. When you are prompted to connect to the J-Mate, click yes and then follow the remaining prompts.

Connecting the TRIUMPH-LS to the J-Mate

TRIUMPH-LS communicates with the J-Mate through Wi-Fi. Turn on both the TRIUMPH-LS and the J-Mate. Click the Wi-Fi icon on the TRIUMPH-LS Home screen to connect to the J-Mate, much the same way as you connect TRIUMPH-LS to your Wi-Fi access point.





After connection, click the J-Mate icon on the TRIUMPH-LS Home screen and then J-Mate/Collect/Next to get familiar with the Main J-Mate screen.

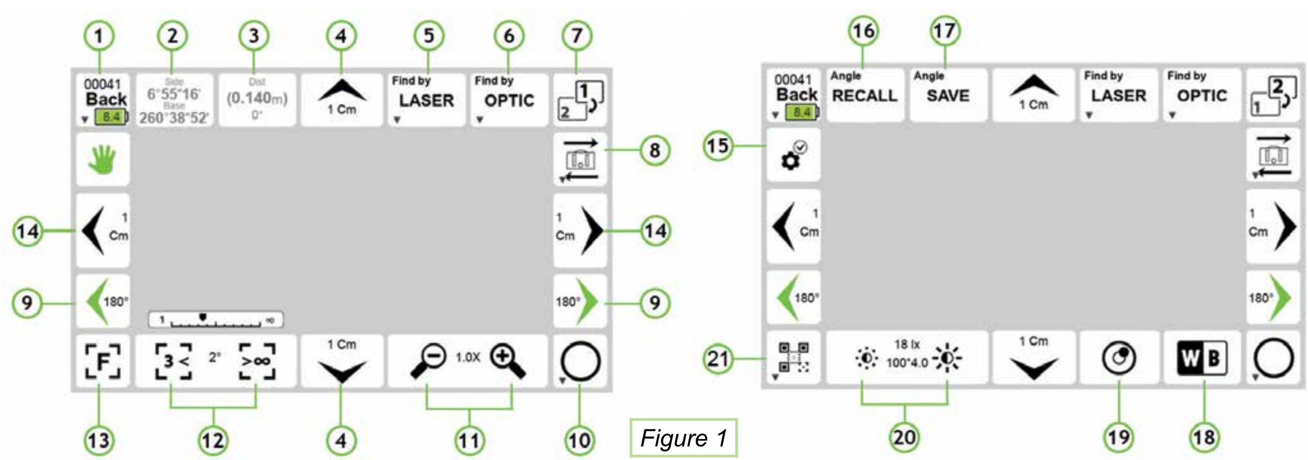
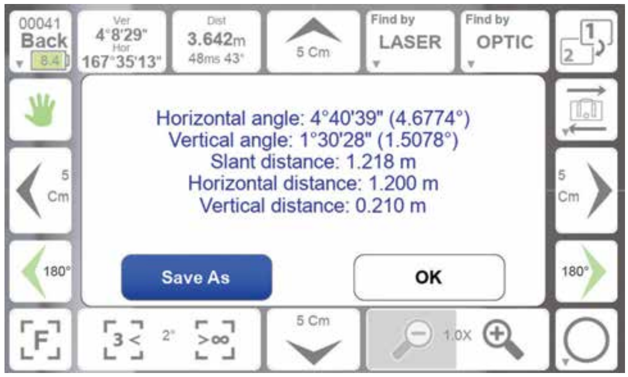


Figure 1

Measure angles between two points:

Aim at the first point and click button **“2”** of Fig. 1. Then Aim to the second point and click this button again. You will see the horizontal angles between the two points. You can save the measured angles in clip boards and use it elsewhere when you need.



Taking a point

Aim at your target and click **“10”**. J-Mate will take 10 readings and average them. The average, RMS and spread of the ten readings are shown. Optionally, you can specify four points around the target point to be measured too, to ensure that you have aimed at the desired target. To specify the distance of the four points around the target, hold **“10”**.

Instantaneous angular and range measurements are shown in boxes **“2”** and **“3”** in Fig. 1.

Camera operation and settings

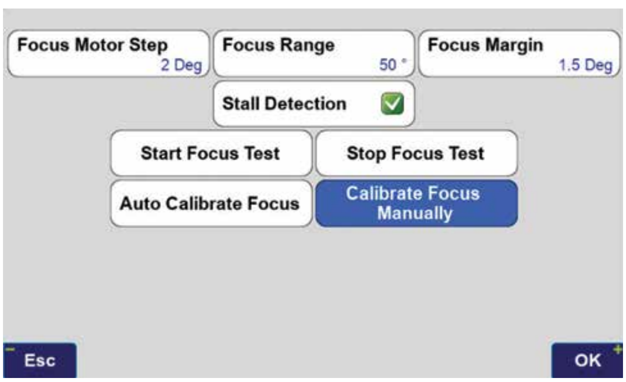
White balancing the J-Mate camera when the light setting changes: 1)Put a white paper in front of the J-Mate camera about few meters away, such that it covers at least half of the viewing angle of the camera. 2) Click **“18”** to start white balancing. It will take about 10 seconds to finish.

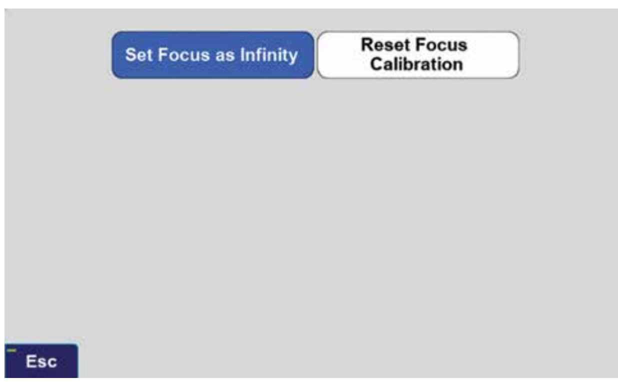
Zoom buttons: **“11”**

Contrast/Brightness buttons: **“20”**

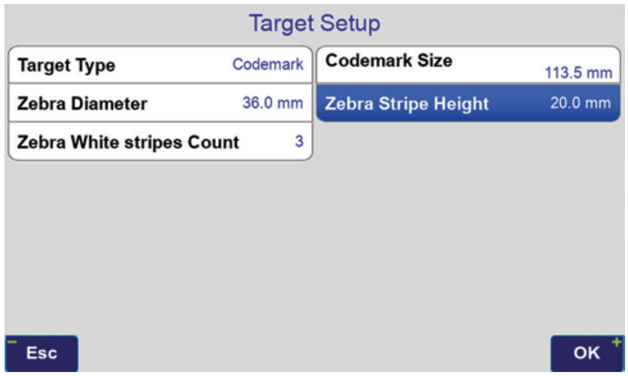
Focus: use buttons **“12”** to focus manually. Click **“13”** for autofocus on the subject.

Occasionally you may need to calibrate the Focus motor. Click Setup **“15”** → “Focus” → “Auto Calibrate Focus” or “Calibrate Focus Manually”. In Manual focus, 1)click “Rest Focus Calibration”, 2) using **“12”** buttons, focus to infinity, 3) Click “Set Focus as Infinity”.





Searching and finding objects by laser and Object types



Hold the Laser button (**“5”**) to see the setup screen for laser target selection and parameters. If you know the approximate distance to the target, click the check box and enter the distance and accuracy percentage. This will help J-Mate to ignore targets that are outside the range.

Horizontal and Vertical Limits are the limits that J-Mate will search around the starting point to find targets. In this example is 15 degrees on left and right, and 15 degrees up and down.

“Keep Fixed Height” check box, scans horizontally on fixed target height. You may rarely need to use this feature. It will reduce the scanning speed by a factor of 2.

In Target Selection screen, the following targets are defined:

- **J-Target** is a printed pattern glued to 166x166 mm plywood of about 25 mm thick. It can be attached to a 226x226 mm plywood of 10 mm which provides flaps around the pattern. Select check boxes related to Sides, Top and Bottom flaps, if they exist and you want J-Mate to consider the depth of the flap (about 25 mm).

- If the J-Target is not sitting on another object and its bottom boundary is clear, then check the box Measure to Bottom. If not checked, J-Mate will measure to the top and will come down half of the height to aim at center. This feature applies to other target types too.

- In laser scanning and finding, the pattern on the J-Target has no effect.

J-Target Custom: This option allows you to build your custom J-Target type.

Zebra: This is a pattern of 3 white stripes on black.

TRIUMPH-LS Back: searching for an object similar to the back of TRIUMPH-LS.

Search Tube: Searches to find a tube with given diameter and height. If Measure to Bottom is not checked, it will go to the top of the tube and then come down half of the specified height, irrespective of the actual height of the tube.

Measure Tube: Searches for a tube that has the given width and then it measures the tube depth.

Corner identifies an abrupt change on a flat surface.

Snap: scans with the resolution given in “Step” and stops when range changes by “Edge Depth”.

Scan: Scans according with the resolution given in “Step” and saves the scanned files if the box is checked. The scanned files can be viewed in the Main screen / Collected by User .

Selected objects and their parameters can be saved and recalled by **“Save”** button on this and **“Recall”** button of the previous screen.

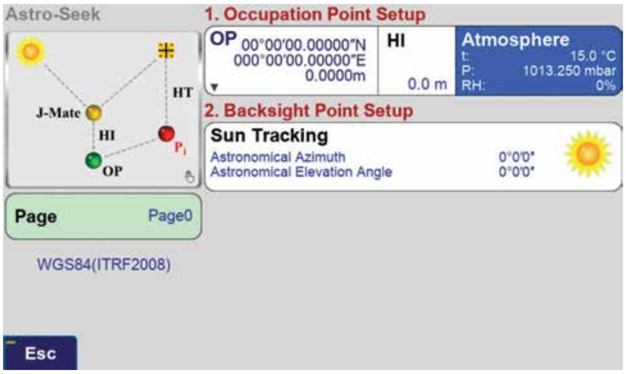
Aiming at targets manually

You can find targets manually or automatically.

Backsight point and the Sun

Similar to using conventional total station, to use the J-Mate you need to first establish its accurate position and calibrate its vertical and horizontal encoders. Then proceed to shoot the unknown points. This is similar to using any total station, but we have improved and automated the process.

With J-Mate you can do these in three different ways as shown in the J-Mate screen of the TRIUMPH-LS. Via the J-Mate Backsight; One Point, Resect, and Astro-Seek icons.



If GNSS signals are available at the site, click the One Point icon.

This screen appears which guides you to determine the accurate positions of the Occupation Point and a Backsight Point to establish an azimuth and calibrate the J-Mate angular encoders.

The tripod is setup at the “Occupation Point” (OP). The J-Mate is secured on top of the tripod.

Next, TRIUMPH-LS is put on top of the J-Mate with its legs registered to the matching features on the J-Mate.

Next Use the RTK Survey feature of the TRIUMPH-LS to quickly determine the accurate location of the Occupation Point. You can use your own base station or any public RTN.

Next, slide the J-Target on top of the TRIUMPH-LS, lift it from the J-Mate and move to the “Backsight Point” (BP). The camera of the J-Mate will search the J-Target. The camera’s view is visible from the TRIUMPH-LS screen, which mostly focuses on this J-Target. When at the Backsight Point, its accurate position is determined by the TRIUMPH-LS, and the Azimuth from the Occupation Point to the Backsight Point is determined, and the J-Mate is calibrated and ready for use.

After this calibration is complete, if the tripod is disturbed, the red LED on the front of the J-Mate will blink to show that re-calibration is required.

We can now replace the TRIUMPH-LS on top of the J-Mate at the Occupation Point and proceed to shooting as many “Target Points” as the job requires. From now on TRIUMPH-LS is used as a controller and you can hold in your hand too, but it is more convenient to put it on its place to have free hands.

If GNSS signals are not available at the Occupation Point, click the “Resect” icon to shoot two known points to establish its accurate position and calibrate its encoders. Then continue to shoot the unknown points.

Astro-Seek feature: Sun as the Backsight point!

We have added a new innovative feature to the J-Mate that it can automatically calibrate itself via its automatic Sun Seeking feature.

Attach the Sun filter to the camera of the J-Mate, click the “Astro-Seek” icon, set Occupation Point, and click the “Sun” icon in the screen which appears and J-Mate will scan and find the Sun, and use its position to calibrate the angular encoders automatically.

See details at **www.javad.com**

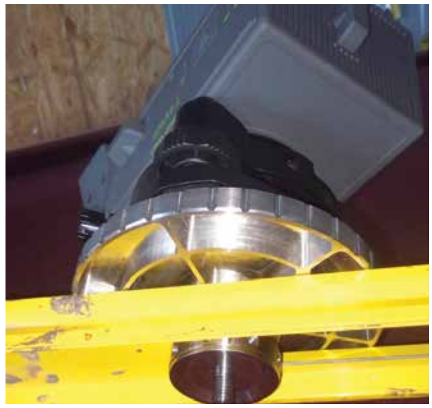
Javad gets a Blue Ribbon for best invert measuring device I've ever used.

No total Station I've seen can do this the way the JMate does. The offset camera/vertical action hasn't been done before and I see huge advantages.

I've measured many inverts in my career. Anyone who says they can measure them to the hundreths with a sh*t stick (pipe mic or not) (handheld laser or not) is full of it. Today I measured the most accurate inverts I ever have. Relative accuracy of a mm or two at most on elevation. Yes the inverts were recessed. I'm embarrassed to tell you folks what I measured with the sh*t stick a few weeks ago and thought it was good. It wasnt, matter a fact it put the sh*t flowing uphill. A tenth or two, sometimes it matters , sometimes it doesn't. JMate gets an A+ plus for this task.

This is the setup I should have used today.

Aluminum 4 ft level, the Jmate top plate and 3/8 3/8 adapter. Quick and Easy. I would have had a better view too.



TRIUMPH-3

The new TRIUMPH-3 receiver inherits the best features of our famous TRIUMPH-1M.

Based on our new third generation TRIUMPH chip enclosed in a rugged magnesium alloy housing.

The TRIUMPH-3 receiver can operate as a portable base station for Real-time Kinematic (RTK) applications or as a receiver for post-processing, and as a scientific station collecting information for individual studies, such as ionosphere monitoring and the like.

It includes options for all of the software and hardware features required to perform a wide variety of tasks.

- UHF/Spread Spectrum Radio
- 4G/LTE module
- Wi-Fi 5 GHz and 2.4 GHz (802.11 a, b, g, n, d, e, i)
- Dual-mode Bluetooth and Bluetooth LE
- Full-duplex 10BASE-T/100Base-TX Ethernet port
- High Speed USB 2.0 Host (480 Mbps)
- High Speed USB 2.0 Device (480 Mbps)
- High Capacity microSD Card (microSDHC) up to 128GB Class 10;
- "Lift & Tilt"
- J-Mobile interface

Ideal as a base station

Back

Bridging the gap between high-altitude remote sensing and ground survey for sampling in the marine environment

In this study we focus on low altitude remote sensing using remotely piloted aircraft system (RPAS) to streamline sampling in the marine environment

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Dr Barbara Bollard
Associate Professor, Institute for Applied Ecology New Zealand, School of Applied Sciences at Auckland University of Technology, New Zealand

Kavita Prasad
Project Management & Field Assistant at Auckland University of Technology, New Zealand

Recent enhancements in satellite remote sensing has increased the value of remotely sensed data for marine ecologist. With a ground sample distance of 31cm for panchromatic nadir and 1.24m for multispectral nadir (WorldView-4) commercial satellite imagery remains best suited for large scale assessment of benthic marine habitats. However, limited resources and budget could be hurdles to procure such imagery. Occasionally satellite data for desired tidal interval is not always available. On the other hand, ground sampling using quadrats is time consuming and requires additional personnel to cover large areas. Therefore, in this study we focus on low altitude remote sensing using remotely piloted aircraft system (RPAS) to streamline sampling in the marine environment. Along temperate coasts of New Zealand, there is a gap in exploring the potential of RPAS as a low altitude aerial photography tool for sampling fine scale biogenic marine habitats. The survey had been conducted during low tide. The results show RPAS covered the area of interest at user define interval within a reasonable time frame. The outputs are high-resolution orthomosaic and other useful digital surface (DSM & DTM) products. These datasets can be using for various applications and explicitly complement other datasets. While other remote sensing and ground sampling are still valuable and cannot be replaced, RPAS data can complement these datasets for marine conservation planning. Additionally, improving efficiency of small to medium projects.

Introduction

The marine ecosystem encompasses ecologically and environmentally valuable habitats. However, due to unprecedented flux in environmental and anthropogenic pressure the need to effectively monitor this precious ecosystem has never been so important. Fundamental to conserving marine biodiversity into the future is the understanding of natural spatial and temporal variability of marine flora and fauna. While making strategic decisions for improved resilience to natural and anthropogenic disturbances.

Therefore, as technology advances and pressure on marine ecosystem increases, the need for a more effective, robust and swift monitoring technique is demanded. Sampling in the marine environment has been multifaceted, here different data collection techniques has been adapted. One of the widely used datasets are satellite imagery. Enhancements in satellite technology over the past two decades have increased the value of remote sensing imagery to marine ecologists (Ventura et al., 2015). With a ground sample distance of 31cm panchromatic nadir and 1.24m for multispectral nadir data (Worldview-4) commercial satellite imagery is one of the best datasets available. However, some ecosystems compose of habitats that are heterogeneous. It is here that this imagery struggles to provide significantly finer details in areas with heterogenous marine vegetation (Ventura et al., 2018).

Classic techniques still exist scuba; snorkeling; and transects (Samoilys & Carlos 2000). Later improvements included visual underwater video; rotating videos apparatus; multibeam; and side-scan-sonar technology (Pelletier et al., 2012). The area covered by scuba operators each time is often limited due to difficulty in manoeuvring in shallow (<5m in depth) rocky waters, leading to the partial identification of habitats (Pereira et al., 2009). Alternatively, these techniques require a deep knowledge of the equipment (e.g. sonar) and trained personnel for operation (Ventura et al., 2018). Have high application costs and unsuitable spatial data and are best suited for deep (> 15m) ocean monitoring and survey (Ventura et al., 2016). The difficulty arises when the interest is aimed at identification and cartographic representation of habitats in estuarine, shallow intertidal, and subtidal (<5-7m) habitats (e.g. seagrass). Quadrats along transects is a promising method however this technique is limited to coverage. Here, marine scientists at ground level can collect high-resolution data, but experience sampling constraints across larger spaces (Johnston, 2018). Hence something more versatile is needed to fill these gaps.

Here low altitude remote sensing using RPAS could be a solution. The evolution of unmanned aerial vehicle (RPAS) for low altitude remote sensing in the marine environments has gained momentum (Kovea et al., 2018). In the marine environment drone applications have focused: on topographic monitoring of coastal areas; intertidal reef monitoring mapping coral reefs; marine mammal research; marine coastal environmental monitoring; mapping, and monitoring of ecologically sensitive marine habitats (Goncalves & Henriques, 2015; Murfitt et al., 2017; Casella et al., 2017; Fiori et al., 2017, Trasvina-Moreno et al., 2017; Ventura et al., 2018).

RPAS (Fig 1) provide essential on-demand low altitude remote sensing capabilities, economically with reduced human risk and are poised to revolutionize marine science and conservation. Equipped with the versatile platform: multirotor, fixed wing and transitional models. RPAS can carry various optical and physical sampling payloads and are employed in almost every sub-discipline of marine science and conservation (Johnston, 2018). Subsequently RPAS can fill the gap in spatial resolution with better coverage (at an altitude of a 100m cover maximum of 2.2 to 2.6 hectares per image) (Johnston, 2018). In the nearshore marine environment, RPAS provide high-resolution ecological data for marine conservation planning (Anderson & Gaston, 2013). For point monitoring on a large spatial scale, RPAS datasets can be fully integrated into a geographic information system (GIS) (Brown et al., 2011; Collin et al., 2018).

Whether it is a marine or terrestrial environment. Determining the **Where** is an important step in being able to assess **Why** behind changes are occurring in an ecosystem. This study will use a multirotor RPAS with MicaSense RedEdge sensor aimed at reducing field time and at the same time acquire high-resolution products for sampling in the marine environment at user specified intervals.

Significance of this study

New Zealand's extensive and diverse marine environment is home to many plants, fish, invertebrates and marine mammal species. Many important to the ecological health and productivity of the marine environment (Ministry for the Environment & Statistics New Zealand, 2016). Yet, the marine environment is highly interconnected, and the impacts of activities in one habitat can have flow-on effects elsewhere making management a great challenge.

Most threats to New Zealand's marine habitats decline with depth at 50 m increments (MacDiarmid et al., 2012). Among the threatened habitats are ecologically sensitive habitats e.g. oysters in intertidal reefs, seagrass in mudflats, mangroves and other vegetation in a saltmarsh (Baird et al., 2011). Ecologically sensitive habitats have critical functions in the wider ocean. These habitats produce oxygen that supports other marine life. Provide nursery grounds for fish and recycle nutrients and human waste and storage of carbon.

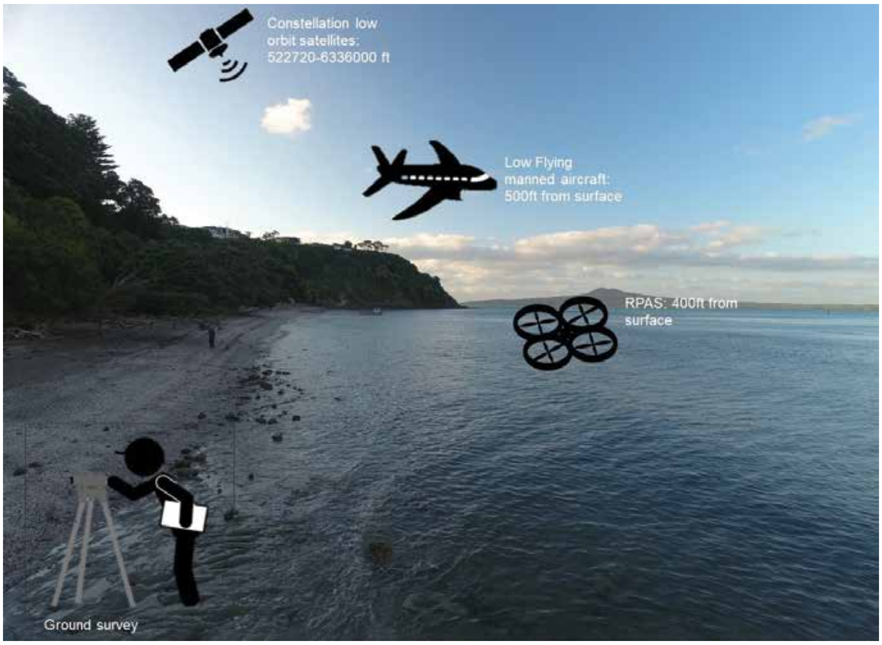

Figure 1. Capability of RPAS to collect low altitude data.

Importance of biogenic habitats?

Benthic habitats support a wide variety of marine organisms by providing grounds for spawning, nursery, and refuge. Benthic organisms are important food web members who consume organic matter and phytoplankton and are food sources for higher-level consumers. Several benthic habitats (for example, oyster and kelp forests) have three–dimensional structures that serve as shelters and provide protection during storms by buffering wave action along coastlines (Casella et al., 2017). Biogenic habitats contribute significant services to the marine ecosystem. This included habitat provision, carbon fixation, and nutrient transport. These habitats, directly and indirectly, support numerous cultural, commercial, and recreational fisheries, including the formation of a unique reef ecosystem. Act as ecosystem engineers and provide a focal point for nearshore ecosystem-based management; hence protection of these habitats ensures long term sustainability of other resources.

Method

Study Site. Aerial survey was conducted on Meola reef (Te Tokaroa) in the North Island of New Zealand. Located -36.853454 S & 174.709982 E, this reef is the largest and most visible natural rocky reef system in the Waitemata Harbor (Fig 1). From satellite during low tide this reef is fully visible and extents over 2km into the Waitemata Harbor. This is an important rocky reef system supporting higher biodiversity of habitats. Habitats include saltmarsh, mangroves, seagrass and oysters. Where mangroves dominate the landward site, oyster dominate the mid-section of this reef and kelp dominate the subtidal.

Flight Safety

Prior to all flights a RPAS operator must ensure that there is no Notice to Airmen (NOTAM) for that location. Check the New Zealand Airspace Maps (https://www.airshare.co.nz/maps) for Fly and No Fly zones. Currently there are six categories where you can and can't fly RPAS in New Zealand. These are Low Flying Zones/orange zone (RPAS not permitted to fly in these zone), Military operated zone/green zone (permission to be sort before flights), Aerodromes/ blue zone (4km radius around aerodromes), Other Authorities zone/purple zone (permission before flights), Control zone/ red zone (managed by Air traffic control) and No Fly Zones (not allowed to fly in these areas).

The maximum flight altitude of a RPAS according to Civil Aviation Authority of New Zealand is 120m (400ft) from surface. All flights should be within the visible line of sight. All flights are to be away from people and private property at all time. A warning sign is displayed depicting a RPAS is operating in the area before flights (Fig 3).

The Setup

A DJI Phantom 4 pro (Fig. 3) retrofitted with a Mica Sense RedEdge sensor, a sun irradiance senor, GPS, Lipo batteries, DJI controller, Apple I-Pad, cables and hardcase carry box.

UAV Survey. During Mean Lower Low Water (MLLW) tide height at 0.3m on 23rd March 2019. The RPAS platform used was a Phantom 4 pro multirotor. The RPAS was retrofitted with a MicaSense RedEdge multispectral senor with five bands Blue, Green, Red, NIR and Red Edge (Table 1).

RPAS data acquisition. Pix4D capture (© 2017 Pix4D) (V. 4.5.0) an open source flight planning software was used to plan the flights. Flight mission were flown at an altitude of 164ft from surface at nadir. Front and side overlap were set to 80% to get an equal distance between the two images on the same flight line. Picture trigger mode in the app was set

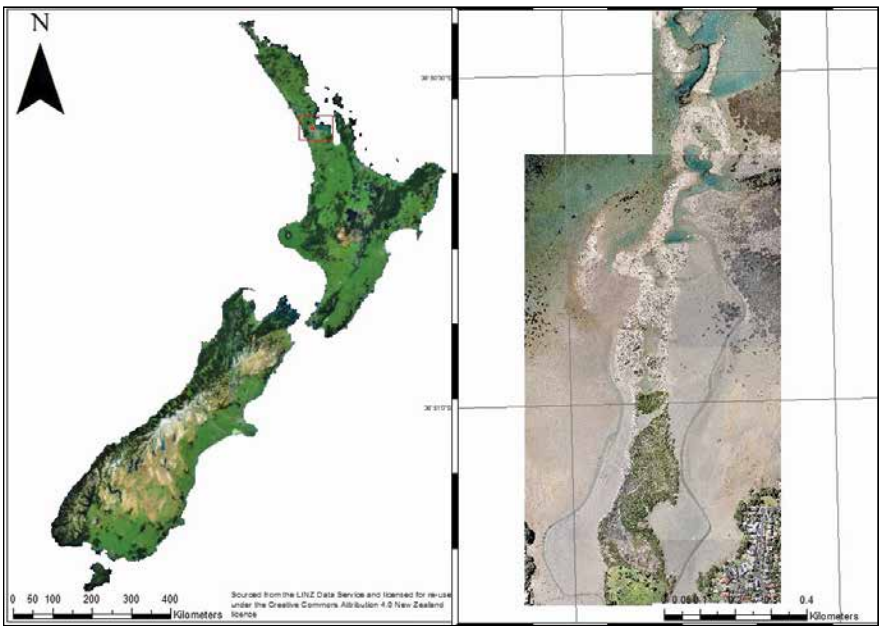

Figure 2. Study area located on the North Island of New Zealand. (Source: LINZ)

Figure 3. Safety warning sign depicting a RPAS is being operated in the area. (Picture taken by Kavita Devi Prasad)

Figure 4. The kit used for data collection. (Picture taken by Kavita Devi Prasad)

Table 1. RedEdge MicaSense Wavelength & Bandwidth.

Band	1	2	3	4	5
	Blue	Green	Red	RedEdge	NIR
Centre Wavelength	475	560	668	717	840
Band Width	20	20	10	10	40

Table 2. Radiometric correction

Camera Name	Band	Radiometric Correction Type	Reflectance target
RedEdge_5.5_1280x960	Blue	Camera and Sun Irradiance	✓
RedEdge_5.5_1280x960	Green	Camera and Sun Irradiance	✓
RedEdge_5.5_1280x960	Red	Camera and Sun Irradiance	✓
RedEdge_5.5_1280x960	NIR	Camera and Sun Irradiance	✓
RedEdge_5.5_1280x960	Red edge	Camera and Sun Irradiance	✓

Table 3. Percentage geolocation error.

	Geolocation Error X (%)	Geolocation Error Y (%)	Geolocation Error Z (%)
RMS Error (m)	0.855529	1.290223	1.272464

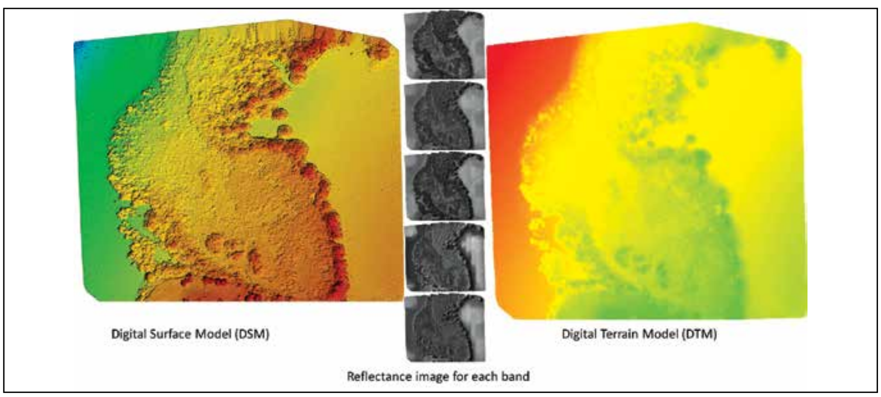

Figure 5. Derivatives of RPAS

to Fast mode since this mode does not require to stop in order to take a picture it is continuous, and the orientation is always maintained. Flight speed was set at 3m/s to avoid blurry images. Flights times was limited to 10 minutes to allow adequate battery for the RPAS to return safely. Ground control point (GCP) were randomly place within the area of interest for accurate geo-referencing of imagery.

RPAS data processing. The imagery collected were geotagged with Pix4D capture prior processing. Full processing was initiated in Pix4D mapper software (V. 4.4.12). Radiometric calibration was applied to each band using values and reflectance panel supplied my MicaSense (Table 2). The initial processing setup automatic tie points are created and GCP are added to the model for accurate georeferencing. After adding the GCP the orthomosaic had an accuracy of 0.02m. Furthermore, the software calculated coordinates of images to create a point-cloud, generated a digital surface model (DSM), digital terrain model (DTM), reflectance corrected images for each band.

Results

Digital output (DSM, DTM & Orthomosaic) created from RPAS have an average ground sampling distance of 3.36cm/pixel (Fig 5). An average geolocation accuracy of 0.02m. Area covered 0.053km^2/5.2961ha. Time for flight was 10 minutes in the field. Total time for initial processing was 01h:44m:19s. Time taken for point cloud densification was 15m:49s and for point cloud classification 01m:26s.

Absolute Geolocation Variance: This represents the percentage of geolocated and calibrated images with a geolocation error in X, Y and Z. This percentage also evaluates the quality of image geolocation. The errors range between interval of -1.5 & 1.5 times the maximum accuracy A_{max} of all images. An error lower than -1.5 * A_{max} or higher than 1.5 * A_{max} means the accuracy values have not set correctly.

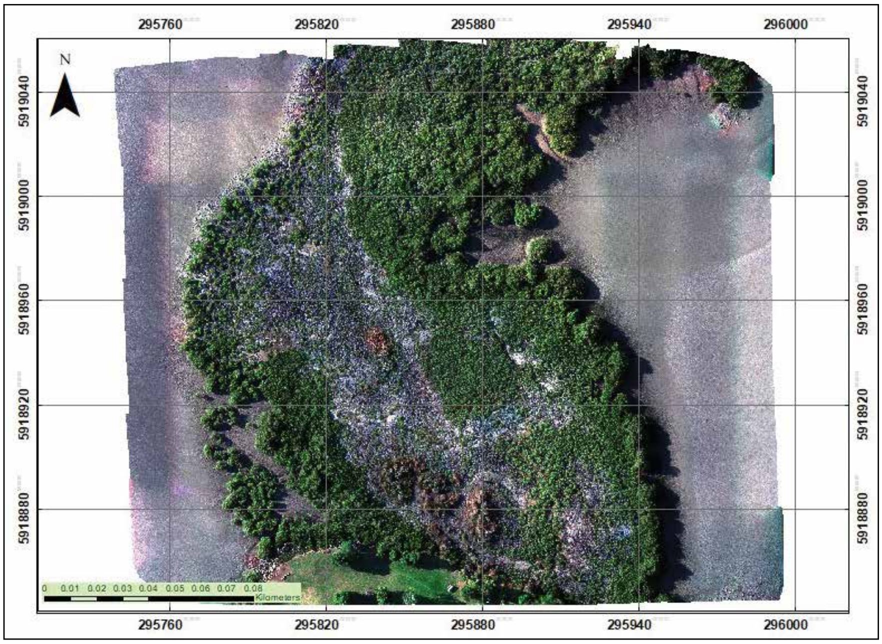

Figure 6. Digital Orthomosaic

Conclusion

RPAS remote sensing is a viable technology for producing high-detail products over user define intervals and for temporal data. The total time taken for field work and data processing were less than 3hrs. This can certainly improve the efficiency of small projects to get faster results. These high-resolution RPAS derivatives can be used for a variety of classification analysis. Including DSM and DTM for surface classification.

Acquiring high-resolution remotely sensed data from commercial satellite operators is not always feasible for small to medium projects. At many times low tide satellite data for marine sampling is not available. The cost of for acquiring data alone would be the total budget for some projects. Here new technologies of low altitude remote sensing using RPAS provide a novel and cost-effective solution for marine research. In addition, this technique of acquiring data is far safer and more reliable than SCUBA or snorkeling. Another critical component of every project is time frame, which many studies have shown the reliability of project delivery. High resolution data analysis and results show more accuracy and provide an important area for research for environmental science. RPAS in the marine environment is getting popular and is important to advance marine environmental research, conservation and management strategies.

The plethora of different RPAS models and miniaturization of sensors provide flexibility for researchers. RGB and multispectral sensors are now readily available in the market. There is no doubt that this technology will lead to more applications in the marine environment and researchers gaining more insights and knowledge about ecosystems previously not explored. There is inevitably always going to be trade-off between detail obtained from field observation and logistics involved, here RPAS can effectively complement the efficiency of any field work.

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Fishermans Bend Digital Twin Project

Harnessing digital capabilities for Sustainable Urban Planning

The Centre for Spatial Data Infrastructures and Land Administration (CSDILA) at the University of Melbourne, Australia, has been chosen by the Victorian Government Land Use Victoria, Department of Environment, Land, Water and Planning (DEWLP), to design and develop a Digital Twin of Fishermans Bend, a significant precinct set to be the largest urban renewal project in Australia, covering approximately 480 hectares in the heart of Melbourne. Fishermans Bend comprises five linked precincts across two municipalities (the City of Melbourne and the City of Port Phillip) and connects Melbourne's Central Business District (CBD) to the Bay. It is expected that by 2050, it will be home to approximately 80,000 residents and provide employment for up to 80,000 people.

A multi-disciplinary team from University of Melbourne lead by Professor Abbas Rajabifard, Director of CSDILA, is working closely with Victorian Government Land Use Victoria to design and develop an advanced geo-analytics and visualisation platform that will enable the capability to create 4D modelling of all physical assets design and condition (above and underground), including precise location and legal boundaries, enabling better decision-making about how to manage current and future infrastructures.

The team is building a Digital representation platform of the past, current, and future of Fishermans Bend, as an innovation and interdisciplinary collaboration project, to enable government and wider industry with a series of applications. In the land administration domain, this unique platform will allow its users to investigate and demonstrate the benefits of a 3D cadastre and to digitally enable integrated planning through the development of a Digital Twin.

A Digital Twin is an intelligent digital replica of reality bridging the virtual and physical worlds. By connecting real-time data to the virtual world, the digital replica can change simultaneously with the physical entity. By adopting a virtual model, various scenarios can be modelled prior to being implemented in the real world. This digital innovation can positively impact various industries with a need to conduct simulation modelling, by reducing the cost of development and maintenance. It is also a great communication tool for users, in every industry, to understand the changes and effects of various phenomena. In essence, Digital Twins are the foundation for how businesses and ecosystems will operate in the future. Through this intelligent project, we can use Artificial Intelligence to improve how we make decisions, how we get around, and how infrastructure is planned.

Building and Implementing a Digital Twin increases the reliability of systems and processes by integrating real-time data, identifying and reducing risk factors, allowing for simulations to analyse the impact of different events such as construction of new infrastructure as well as to enable more efficient planning. The main challenges encountered in implementing Digital Twins includes a lack of efficient platforms to support requirements of Digital Twins for different industries, limitations of required data - particularly regarding real-time data availability, the organisation of data ownership, the integration of different types of data and having up-to-date and accurate map data (road networks, road attributes, land parcels, building footprints, building height, DTM, traffic, venues, public transit data, green areas and so on) as a foundation of a digital twin. To overcome such challenges, it is imperative to have a broad and in-depth knowledge of the target industry.

The Fishermans Bend Digital Twin Project is an opportunity to lead the generation of scientific evidence and prepare for the challenges ahead. It will allow us to encompass a better understanding of our changing environment and to support our societies using location intelligence technologies. It is also a step towards addressing a range of unresolved challenges confronting urban renewal, city planning and digital cadastre modernisation. By collaborating with a number of key stakeholders, the objective of the project is to develop, validate and show case a multi-disciplinary (and cross-government) testbed for addressing the challenges involved in aggregating, managing and visualising complex and multi-faceted (4D) digital information about cities in an interoperable way. The intended purpose of the testbed is to provide a foundation upon which various government stakeholders can build intelligent, innovative digital information systems (either independently or collectively) that will satisfy future (whole-of-government) initiatives for the coordinated management of smart, sustainable and liveable cities, suburbs and regional centres.

The project adopted FAIR Data Principles (Findable, Accessible, Interoperable, Reusable) and enables the spatial information to be searched, discovered, aggregated and visualised seamlessly, irrespective of database management system, data model, data content (raster, vector, metadata, etc.), data server or preferred application.

By leveraging capabilities and technical resources in Spatial Data Infrastructures (SDI), 3D Cadastre, Digital Engineering, and spatial enablement of the urban and regional planning and decision making, and in close collaboration with wider government and industry, the Fishermans Bend Digital Twin project is a model of an innovative ecosystem that enhances Victoria's liveability and Melbourne's goals as a smart and sustainable city. The project has establish and promote:

- a collaborative environment comprised of relevant stakeholders across state and local government to foster information and data sharing, innovation and addressing challenges common to all
- the modernisation of land administration by implementing 3D land and property information
- a more responsible approach to the urban renewal and precinct planning activities to maximise the achievement of sustainable future for all
- United Nations Sustainable Development Goals realisation in Australia.

The design team is pioneering state-of-the-art technologies to integrate multi-dimensional data, visualise and interact with multi-sources information to modernize the urban planning and land administration. The Fishermans Bend Digital Twin project will ensure a more responsible approach to the urban renewal and precinct planning activities, and provide the foundations for a live testbed that will in turn support the achievement of a sustainable future for all.

The project started in June 2019, and was launched on August 23 2019 by the Victorian Minister for Planning Hon. Richard Wayne MP, to showcase the earlier capabilities. Over the first three months, the project has progressed very well and already showing how to bridge the gap between the Physical and Virtual World, and also to test future scenarios and technologies using location intelligence technologies.

A showcase of capabilities of the Digital Twin Project can be seen in this news: https://youtu.be/UL-TuwTAi0g

or via the CSDILA homepage – from the News and events tab: http://www.csdila.unimelb.edu.au/news/digital-twin-launch-2019/

For more information about the project, contact Director of CSDILA, Prof Abbas Rajabifard, abbas.r@unimelb.edu.au

About CSDILA

CSDILA is a Research Centre committed to excellence in research, innovation and training with a strong focus on future-proofing research. We focus on modernization of land administration systems and the role of spatial information in supporting changing modern societies and spatially enabled government and industry. www.csdila.unimelb.edu.au

Spatial ETL with Talend

Disy Informations systeme GmbH has enriched the Spatial ETL plug-in „GeoSpatial Integration for Talend“ with new functionalities to suit the latest Talend version 7.2. Companies and authorities using the linear reference system for calculations and map presentations can now use the Talend platform, including the spatial add-on for calculations, in the data integration process. It includes functionalities for linear referencing (LRS) as of version 2.1. *www.disy.net/geospatial-en*

Esri ArcGIS QuickCapture supports Arrow GNSS Receivers on iOS, Android, and Windows

Eos Positioning Systems, Inc.® (Eos), the leading manufacturer of high-accuracy Arrow GNSS receivers for GIS users and field mappers recently announced that Esri's ArcGIS QuickCapture GNSS receiver support includes all Arrow Series™ models for iOS, Android and Windows.

ArcGIS QuickCapture is location intelligence world leader Esri's simple, high-productivity rapid-data collection mobile app. Users in the office configure simple interfaces before data-capture begins, so that users in the field need only to tap large buttons, initiating the capture of feature categories (e.g., points, lines, polygons) loaded with pre-configured attributes. Arrow GNSS receivers provide survey-grade accuracy to ArcGIS QuickCapture as frequently as 10 (or 50Hz) positions per second. *esri.com.*

Ordnance Survey in machine learning coup

Ordnance Survey (OS) is on the verge of a quantum leap in its data capture after being granted access to a supercomputer to develop machine learning techniques that will extract extra information and features from aerial imagery and mapping.

The Science and Technology Facilities Council (STFC) Hartree Centre's supercomputer being used is, appropriately for OS, named Scafell Pike. It is expected that if successful this will lead to new business opportunities for OS at home and internationally.

This news builds on OS's already successful work with artificial intelligence (AI) and machine learning to date. It was used to capture and accurately map 373, 919km of England's farmland hedges to create a new digital dataset for the Rural Payments Agency, and was deployed in a joint project with Microsoft that saw a machine learn and identify different roof types – it went from zero to 87% accuracy in just five days.

New Context and INL to Develop Operational Cybersecurity Technology

New Context, a leading innovator in cybersecurity research for highly regulated industries, has announced its ongoing collaboration with the U.S. Department of Energy (DOE) and the Idaho National Laboratory (INL) to research and develop next-generation operational technology (OT) cybersecurity tools. These technologies will strengthen the protection of U.S. critical infrastructure, including the electric grid, from cyber threats. *info@newcontext.com*

GeoTIFF v1.1 adopted as an OGC Standard

The membership of the Open Geospatial Consortium (OGC) has approved version 1.1 of the GeoTIFF Encoding Standard. It formalizes the existing GeoTIFF specification version 1.0 by integrating it into OGC's standardization process. Additionally, v1.1 aligns GeoTIFF with the on-going addition of data to the EPSG Geodetic Parameter Dataset while maintaining backward compatibility with GeoTIFF 1.0. The GeoTIFF format is used throughout the geospatial and earth science communities to share geographic image data.

Christopher Lynnes, NASA/GSFC, System Architect of the Earth Observing System Data and Information System, commented "With the approval of GeoTIFF 1.1 by the Open Geospatial Consortium, NASA has approved GeoTIFF as a standard format for Earth Observation standard products. This will allow production of appropriate NASA data products in GeoTIFF, a format that has been requested by the many GIS users in the user community."

Emmanuel Devys, IGN and DGIWG Imagery and Gridded Data Technical Panel lead, commented "GeoTIFF 1.1, as an international standard, allows the DGIWG GeoTIFF profile to rely on a standardized GeoTIFF standard inline with the modern EPSG register for the production of its elevation data, orthoimages, and raster maps products, or for such production by DGIWG nations. IGN and, more generally in Europe, all mapping agencies may now rely on a modernized and maintained specification for their raster or gridded products, such as the INSPIRE Orthoimagery and Elevation data specifications."

The Geographic Tagged Image File Format (GeoTIFF) specifies the content and structure of a group of industry-standard tag sets for the management of geo- referenced or geocoded raster imagery using Aldus-Adobe's public domain Tagged Image File Format (TIFF). GeoTIFF defines a set of TIFF tags provided to describe all "Cartographic" information associated with TIFF imagery that originates from satellite imaging systems, scanned aerial photography, scanned maps, digital elevation models, or as a result of geographic analyses. The goal is to provide a consistent mechanism for referencing a raster image to a known model space or earth-based coordinate reference system, and for describing those coordinate reference systems.

Approval of this GeoTIFF 1.1 standard begins the process of integration of the GeoTIFF standard into other parts of OGC's standardization process. The Libgeotiff development version (future version 1.6.0) and the GDAL development version (future version 3.1.0) both support this GeoTIFF 1.1 version.

The evolution of GeoTIFF after this version 1.1 depends upon community requirements, with several potential evolutions already under consideration by OGC.

Dr Santiago Perea Diaz receives Parkinson award

The Institute of Navigation's (ION) Satellite Division presented Dr. Santiago Perea Diaz with its Bradford W. Parkinson Award September 20, 2019 at the ION GNSS+ Conference in Miami, Florida.

Dr. Perea Diaz was recognized for graduate student excellence in Global Navigation Satellite Systems in his thesis, "Design of an Integrity Support Message for Offline Advanced RAIM". *ion.org*

HawkEye 360 awards contract to build next-generation satellite constellation

HawkEye 360 Inc., the first commercial company to use formation flying satellites to create a new class of radio frequency (RF) analytics, has awarded the manufacturing contract for its next generation of satellites.

UTIAS Space Flight Laboratory (SFL) will manufacture the bus and integrate the new RF payload developed by HawkEye 360. The satellites will geolocate more signals across a wider frequency range with improved accuracy and reduced data latency for more timely delivery to customers. *www.he360.com.*

China launches two new BeiDou satellites

China successfully sent two satellites of the BeiDou Navigation Satellite System (BDS) into space from the Xichang Satellite Launch Center in Sichuan Province at 5:10 a.m. on September 23, 2019.

The two satellites are medium earth orbit (MEO) satellites and are the 47th and 48th satellites of the BDS satellite family.

After in-orbit tests, the new satellites will work with BDS satellites already in orbit to improve the positioning accuracy of the system.

Compared with previously launched MEO satellites, these two are equipped with lightweight hydrogen maser clocks, which will serve as a more stable precision frequency reference to make the satellite navigation system work more accurately.

The two satellites are also equipped with new processors to improve navigation signals. *www.xinhuanet.com*

GSA funding opportunity: Enhanced GNSS Receiver/User Terminal

The European GNSS Agency (GSA) has opened a call for proposals within its Fundamental Elements funding mechanism, targeting the implementation of OS-NMA and/or I/NAV features in close-to-market receivers and/or GNSS user terminals. The deadline for submissions is 31 October 2019.

This Call for Proposals aims to implement OS-NMA and/or I/NAV improvements capability in close-to-market (i.e. min TRL 7) receivers and/ or GNSS user terminals suitable for target application domains other than the Smart Tachograph. *www.gsa.europa.eu*

French railways embrace Galileo

The French national rail company SNCF is taking a lead in adopting Galileo technology to boost customer services, in particular in its high-speed TGV network. With almost 50% of TGV trains already equipped with Galileo receivers, European GNSS is enabling improved customer information and traffic management.

Satellite positioning and geolocation technologies, like Galileo, are among the main technology building blocks that can precisely and safely locate trains and contribute to the future evolution of the European Rail Traffic Management System (ERTMS). Implementation of the ERTMS aims to harmonise signalling systems across Europe and European GNSS can help to reduce its costs.

French national rail company SNCF is already embracing GNSS-based systems, in particular for passenger information, and fleet and traffic management. "At the beginning of 2019, some 250 high-speed trains were already equipped with Galileo-ready receivers. This represents nearly 50% of SNCF's TGV fleet. Some 320 trains are expected to be Galileo-ready by the end of 2019" said Antoine Barre, Head of Train localisation projects from SNCF. *www.gsa.europa.eu*

Galileo reaches 1 billion smartphone users

Galileo, Europe's satellite navigation system, has reach 1 billion smartphone users worldwide. This milestone coincides with the 15th anniversary of the European Global Navigation Satellite Systems Agency (GSA), the Commission's key partner in operating Galileo.

Since December 2016, Galileo provides so-called "initial services" which already improve everyday life for citizens and businesses with accurate positioning, navigation and timing signals.

Today 95% of companies that produce smartphone chips for satellite navigation make chips that enable Galileo. The '1 billion users' milestone is based on the number of smartphones using Galileo sold across the world. The actual number of Galileo users is larger. In Europe, all new car models approved for the market are equipped with the eCall system, which uses Galileo to communicate the vehicle's location to emergency services. Since this year, Galileo is integrated in the digital tachographs of lorries – a speed and distance recording device – to ensure the respect of driving time rules and improve road safety. *https://europa.eu/rapid/press-release_IP-19-5529_en.htm*

Australian Government purchases GNSS jamming & spoofing detection

Australia's Department of Defence has awarded AUS$28 million (about $19 million U.S.) to a range of technology companies for cutting-edge concept exploration and technology demonstration. Four of the 15 awarded projects involve satellite technology, and one of them, given to GPSAT Systems Australia Pty Ltd, is to develop GPS jamming and spoofing countermeasures.

The Melbourne-based company has developed its GNSS RF Interference FINder (GRIFFIN) technology over the better part of the last decade. The AUS$1.1 million ($750,000 U.S.) Defence contract is for three complete preliminary systems of GRIFFIN technology Phase III, with deliveries scheduled Q4 2019.

"All the underlying research and development work was completed and successfully demonstrated/validated back in mid 2017 under an earlier defence contract," said GPSAT Systems managing director Graeme Hooper.

Orolia introduces New GNSS Testing and Simulation Portfolio

Orolia has introduced its new GPS/GNSS Testing and Simulation portfolio, including the new GSG-8 advanced simulator. Orolia's new Testing and Simulation portfolio offers a comprehensive array of GNSS validation technology, as well as signal and PNT data protection through jamming/spoofing detection, suppression and countermeasure solutions. These capabilities are built on Orolia's legacy of Resilient PNT solutions, together with two key acquisitions completed this year: Skydel Solutions and Talen-X. These industry leading GNSS testing and simulation companies were selected based on their demonstrated testing and simulation experience. *www.orolia.com*

Navigation Satellite System for LTE " in 3GPP

ISRO has introduced NavIC with seven IRNSS satellites as an autonomous regional navigation system with the objective of offering Positioning, Navigation and Timing services to the users in its service area. Currently in India we use GPS (controlled by USA) in our mobile devices. Russia has introduced GLONASS and China has introduced BeiDou as the navigation systems using their own satellite constellations. These have been made part of the 3GPP Specifications. NavIC from ISRO is a regional navigation system that is better suited for Indian requirements.

For the widespread use of NavIC it is necessary that the services become available on mobile devices. World over mobile devices follow standards created by 3GPP. Therefore, it was imperative to include NavIC system in the relevant specifications of 3GPP at the earliest. The next release of 3GPP specifications (Release 16) are due to be finalised by March 2020.

Telecommunications Standards Development Society (TSDSI) members with inputs from ISRO and Reliance JIO as rapporteur, have successfully introduced NavIC as a work item in the 3GPP RAN plenary meeting held in Newport Beach, CA, USA on 21st September 2019.

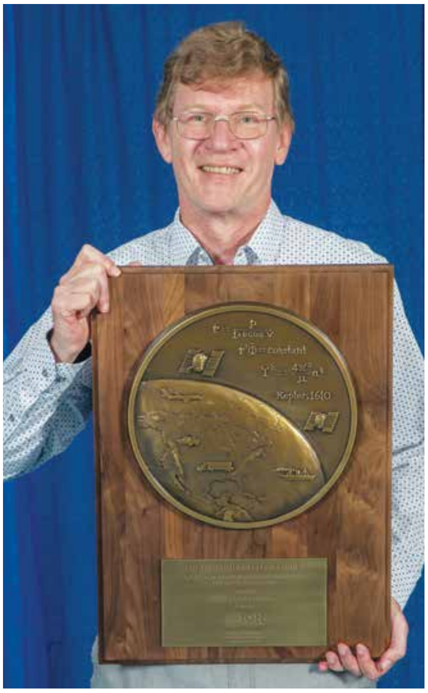
Implication is that 4G and 5G devices with NavIC capability can use assisted-NavIC solution in place of or in addition to other constellations. The specifications will be available in March 2020 and TSDSI will adopt these specifications as a TSDSI standard. This success will enable the introduction of chipsets and devices with this feature within 2020. This is a significant achievement for India and TSDSI. *https://tsdsi.in/tsdsi-enables-inclusion-of-work-item-on-support-for-navic-navigation-satellite-system-for-lte-in-3gpp/*

Professor Peter Teunissen receives kepler award

The Institute of Navigation's (ION) Satellite Division presented Professor Peter Teunissen with its Johannes Kepler Award September 20, 2019 at the ION GNSS+ Conference in Miami, Florida. Professor Teunissen was recognized for his influential and groundbreaking contributions to the algorithmic foundations of satellite navigation, and for sustained dedication to the global education of the next generation of navigation engineers.

Prof. Teunissen invented the Least Squares Ambiguity Decorrelation Adjustment (LAMBDA) method, the worldwide standard for ambiguity resolution, which revolutionized high precision GNSS positioning capabilities. LAMBDA has thus become an indispensable tool that is most widely used in land, air and space navigation; positioning and attitude determination; differential and network processing; and in surveying and geodesy. He also extended the method to MC-LAMBDA, a multivariate constrained resolution method for optimal GNSS attitude determination.

Among others, Prof. Teunissen laid the mathematical and algorithmic foundation of reliability theory, which enables a proper understanding of the quality of different integer ambiguity resolution methods and a rigorous characterization of their failure rates, which even led to the development of an optimal test for ambiguity validation. His findings are particularly important for multi-GNSS processing, which require a proper understanding of individual system characteristics and their respective contributions to achieve navigation solutions of the highest precision and integrity.



Prof. Teunissen has made significant contributions to educating future generations. He is currently a Professor of Satellite Navigation at Delft University of Technology, The Netherlands and Curtin University, Australia. He received his PhD at Delft University of Technology in Mathematical and Physical Geodesy. *ion.org*

FARO® introduces 3D Solutions for AEC Industry

FARO® is previewing an innovative set of 3D solutions specifically developed for AEC professionals.

The FARO Indoor Mobile Scanning solution enables kinematic 3D scans to be completed up to 7X faster than a series of traditional, fixed point scans over comparable areas. Thus, projects that took days can be executed in just a few hours. Additionally, as the Mobile Scanner includes fixed scan capability as a standard feature, users can simply switch to high-fidelity scan mode in real time for seamless integration with mobile scan data. *www.faro.com/in*

Delair to provide flexible access to cloud-based drone photogrammetry

Delair has announced its unlimited photogrammetry plan, available through its cloud-based delair.ai visual intelligence platform. The flexible plan offers a fixed-monthly subscription fee to access delair.ai to create digital maps and models, while managing the data on a secure and scalable cloud architecture which supports additional functionalities such as data sharing, advanced analytics, annotations, and more. *www.delair.aero.*

Airbus completes ocean satellite Sentinel-6A

Airbus has completed the ocean satellite 'Copernicus Sentinel-6A', and is now sending it on its first journey. Its destination: Ottobrunn near Munich in Germany, where over the next six months the satellite will undergo an extensive series of tests at Industrieanlagen Betriebsgesellschaft mbH(IABG) to prove its readiness for space.

'Copernicus Sentinel-6' will carry out high-precision measurements of ocean surface topography. The satellite will measure its distance to the ocean surface with an accuracy of a few centimetres and, over a mission lasting up to seven years, use this data to map it, repeating the cycle every 10 days. It will document changes in sea-surface height, record and analyse variations in sea levels and observe ocean currents. Exact observations of changes in sea-surface height provide insights into global sea levels, the speed and direction of ocean currents, and ocean heat storage. These measurements are vital for modelling the oceans and predicting rises in sea levels. *AirbusMedia*

GSA, EIB sign agreement

The EIB and the European Global Navigation Satellite Systems Agency signed an agreement to cooperate on supporting investment in the European space-based service economy. The signature took place in Prague during the celebration to mark the 15th anniversary of GSA.

To explore new investment support for the European space-based economy, the EIB and GSA are bringing together their expertise and experience. The common objective is to create high-skill jobs in the EU and improve the day-to-day lives of Europeans by supporting innovative companies and accelerating the development of new applications that use European global navigation satellite systems and earth observation data.

According to a recent EIB and European Commission study on the future of the European space sector, European space entrepreneurs feel there is a lack of private financing sources, particularly for late-stage investments. They therefore tend to keep an eye on private capital outside the EU, especially in the US. *www.gsa.europa.eu*

Remote sensing shows scenic spot Jiuzhaigou recovering from earthquake

Remote sensing research shows that Jiuzhaigou scenic spot in southwest China's Sichuan Province is recovering from an earthquake in 2017, according to the Chinese Academy of Sciences (CAS).

Researchers from the Aerospace Information Research Institute under the CAS and UNESCO's International Center on Space Technologies for Natural and Cultural Heritages (HIST) combined satellite remote sensing, UAV low-altitude remote sensing system as well as field investigation to monitor and evaluate the environmental changes in Jiuzhaigou.

After analyzing the remote sensing images, researchers found that after two years of natural restoration, the vegetation ecology in the core area of Jiuzhaigou has gradually recovered to the pre-earthquake level. However, it is still necessary to guard against geological disasters such as landslides and mudslides. *www.xinhuanet.com*

China launches new remote-sensing satellites

Five new remote-sensing satellites were sent into planned orbit from the Jiuquan Satellite Launch Center in northwest China's Gobi Desert.

The satellites belong to a commercial remote-sensing satellite constellation project "Zhuhai-1," which will comprise 34 micro-nano satellites, including video, hyperspectral, and high-resolution optical satellites, as well as radar and infrared satellites.

The carrier rocket was developed by the China Academy of Launch Vehicle Technology, and the satellites were produced by the Harbin Institute of Technology and operated by the Zhuhai Orbita Aerospace Science and Technology Co. Ltd. *www.xinhuanet.com*

NASA announces new tipping point partnerships

NASA has selected 14 American companies as partners whose technologies will help enable the agency's Moon to Mars exploration approach.

The selections are based on NASA's fourth competitive Tipping Point solicitation and have a combined total award value of about $43.2 million. This investment in the U.S. space industry, including small businesses across the country, will help bring the technologies to market and ready them for use by NASA. *www.nasa.gov*

Vexcel Imaging launches Europe's High Aerial Image Library

Vexcel Imaging has announced the launch of Europe's highest quality and most up-to-date aerial image library. Starting in Germany, the cloud-based image library, now available via subscription service, enables companies, public safety organizations and government agencies to save a significant amount of time and money by making it fast and simple to acquire up-to-date, concise, high-definition imagery and leverage it organization-wide into critical location intelligence.

Starting with orthorectified imagery at 20 cm resolution, the subscription service also includes near-infrared imagery and derivative data products such as digital terrain models, making it easy for organizations to integrate geospatial location information into their tools and workflows.

Vexcel Imaging is in the process of capturing aerial imagery of Germany at 20 cm with its UltraCam Condor Mark 1 Airborne System. *www.vexcel-imaging.com*

Leica CityMapper-2

Leica Geosystems introduces the Leica CityMapper-2. This next-generation hybrid oblique imaging and LiDAR sensor provide fast and efficient digitization of cities.

The new sensor is designed to provide faster updates while preserving image quality over a wide range of flying conditions.

The most significant improvement comes from the newly developed optical system incorporating two nadir (RGB & NIR) and four oblique 150 MP metric cameras using CMOS technology and equipped with Leica Geosystem's unique mechanical forward-motion-compensation (FMC). The LiDAR sensor's pulse repetition frequency has been increased to 2 MHz and features gateless Multiple-Pulses-in-the-Air (MPiA) technology.

Development of positioning technology for autonomous vehicles by GMV

GMV has announced the award of an important contract for development of a precise satellite-based (GNSS) positioning system with integrity for the new generation of autonomous vehicles of the German carmaker BMW Group.

The Spanish multinational's technology solution is going to be developed for the first time in BMW Group's autonomous vehicles. This positioning software calculates the vehicle's position and other magnitudes, using advanced GMV-developed algorithms, including components that have already been patented.

These algorithms have been especially modified and adapted to meet BMW Group's performance and safety requirements. *www.gmv.com*

Advanced localization technology for autonomous vehicles

Septentrio is providing positioning technology to Artisense, supplier of innovative computer vision solutions for automated vehicles. Artisense incorporates Septentrio GPS/GNSS in their latest Visual Inertial Navigation System (VINS). VINS combines computer vision, inertial sensors and GNSS measurements to deliver highly accurate global 3D positioning and orientation information in any environment, even indoors. *septentrio.com*

Trimble and Qualcomm establish alliance

Trimble and Qualcomm Technologies have announced plans to work together to produce precise-positioning solutions for select automotive applications. Trimble will work with Qualcomm Technologies to integrate Trimble's RTX® technology with select Qualcomm® Snapdragon™ Automotive 4G and 5G platforms to deliver a highly accurate positioning solution essential for maintaining absolute in-lane positioning. This new solution will accelerate the adoption of road-level navigation and emergency services applications, as well as satisfy requirements for developing Advanced Driver-Assistance Systems (ADAS) and autonomous driving solutions.

Qualcomm Technologies' Snapdragon 4G and 5G Automotive platforms feature integrated multi-frequency and multi-constellation high-precision GNSS technology. Trimble RTX technology provides real-time, multi-constellation GNSS corrections and positioning capable of achieving 2-centimeter horizontal accuracy worldwide, compared to uncorrected GNSS positioning that can be accurate to several meters. *https://positioningservices.trimble.com*

LG Electronics, Unity Technologies collaboration

Engineers at the LG Electronics America R&D Center in Silicon Valley are working with Unity Technologies to develop advanced simulation software that will enable autonomous vehicle developers to accelerate system development for safer self-driving cars.

The collaboration of LGSVL Simulator on Unity Simulation leverages LG's AI leadership and expertise as a leading technology partner to the global automotive industry, combined with complementary skills of Unity Technologies, creator of the world's leading real-time 3D development platform.

Training and validating an autonomous vehicle is a prime example of how a virtual environment can dramatically reduce the risk for both the car and those around it, allowing businesses to stress-test systems before they are put on the road. The LGSVL Simulator combines LG-developed technologies with Unity's High-Definition Render Pipeline to enable testing and training for safer operation of autonomous vehicles. *www.LGnewsroom.com*

Actility and Hiber join forces to power remote iot connectivity

Actility, the leading LoRaWAN connectivity provider and Hiber, the startup nano-satellite powered IoT network, have announced that they are collaborating to enable LoRaWAN connectivity in the remote and developing parts of the globe that until now haven't had access to a network. IoT (Internet of Things) service providers and enterprises operating in these areas will now be able to benefit from Hiber global nano-satellite connectivity via the Actility ThingPark Wireless and ThingPark Enterprise LoRaWAN management services.

The collaboration will enable IoT use cases in hard-to-reach places all over the world. The global logistics, remote agriculture, oil & gas, mining and scientific sectors are amongst many that can now deploy IoT technology in areas such as the Antarctic, deserts or in the middle of Pacific Ocean.

Facebook is Working on AR Glasses With 3D 'Live Maps'

Facebook had already announced that it will make Augmented Reality glasses or AR glasses. Now Ray-Ban maker Luxottica has now confirmed that it is actively working towards developing augmented reality glasses, with plans to recreate the world in a 3D map. The company is working towards providing an enhanced and interactive living space.

The confirmation came in from Facebook Inc. on September 25, when it announced a project called "Live Maps" that will create 3D maps of the world. Andrew "Boz" Bosworth, vice president of AR/VR at Facebook described the maps project as "a shared virtual map of the world" at the Oculus Connect developer conference. At the same conference, Facebook shared a lengthy video presentation confirming the company's intention to build the augmented reality glasses. *www.news18.com*

Applanix releases New POSPac LiDAR Quality Control Tools for UAVs

AApplanix has introducedLiDAR Quality Control (LiDAR QC) Tools for Unmanned Aerial Vehicles (UAVs)—a new software module supported by the latest release of Applanix' industry-leading GNSS-aided inertial post-processing software packages, POSPac Mobile Mapping Solution (MMS) and POSPac Unmanned Aerial Vehicles (UAV). LiDAR QC Tools for UAVs are specifically designed to achieve higher accuracy LiDAR point clouds from a UAV by performing two key functions: Inertial Measurement Unit (IMU) boresight calibration and trajectory adjustment. *www.applanix.com*

Enhanced Cut-and-Fill Mapping in drone surveying package

Virtual Surveyor has added cut-and-fill mapping capabilities to Version 7.0 of its popular drone surveying package. The new functionality enables users to quickly perform volume difference calculations and generate cut-and-fill maps from drone images captured on two or more different dates. The enhanced cut-and-fill functions are part of a new feature in Virtual Surveyor 7.0 called Terrain States. This allows the user to create separate Terrain States for surface models generated from UAV images captured over the same area on different dates. *www.virtual-surveyor.com.*

Yuneec and Leica Camera AG announce partnership

Yuneec and Leica Camera AG announced the beginning of a strategic partnership today. The first result of this collaboration was presented in the form of the Typhoon H3 with ION L1 Pro camera. It is a drone equipped with a high-end 1" sensor camera that was specially developed for sophisticated aerial photography and, thanks to Leica photo-engineering technology, also meets the highest standards of quality. Both the software and the hardware of the ION L1 Pro camera were developed in collaboration with Leica engineers, which means the device is characterized by its outstanding image quality, intuitive operation that is typical of Leica, professional image-processing options and the iconic Leica industrial design. *www.yuneec.com*

First-of-its-Kind Trial with FedEx and Walgreens

Wing Aviation LLC, an Alphabet company, is collaborating with FedEx Express and Walgreens to launch a first-of-its-kind drone delivery service in Christiansburg, Virginia next month. The pilot program will demonstrate the many benefits of drone delivery to communities by exploring methods to enhance last-mile delivery service, improve access to health care products, and create a new avenue of growth for local businesses.

Drone delivery in the United States has historically been limited to small-scale demonstrations on designated test sites, or extremely short flights along pre-planned, fixed routes – all within the visual line of sight of the drone operator. Earlier this year, Wing became the first drone operator to be certified as an air carrier by the Federal Aviation Administration, allowing it to deliver commercial goods to recipients that may be miles away. Wing's pilot program in Virginia will be conducted as part of the U.S. Department of Transportation's Unmanned Aircraft System Integration Pilot Program (IPP). *wing.com*

MMC UAV launches Hydrone

MMC UAV recently launched its new hydrone Griflion H, with a record-breaking 15-hour flight time. It is a hydrogen-powered vertical take-off and landing drone with an integrated design and MMC-developed hydrogen fuel battery with great stability.

The highlight of Griflion H is the extended flight time thanks to its high-efficiency metal bipolar plate hydrogen fuel cell with a maximum hydrogen storage capacity of 27L. Its flight time reached a record-breaking 15 hours without payload and 10 hours with a 3kg payload while most drones in market merely have a maximum 2-hour flight time. In mapping practice, the mission is usually interrupted by multiple take-offs and landings in different spots and hence lower efficiency. The extended flight time of Griflion H greatly improves mission efficiency. Other features include convenient operation, high security, wide coverage, zero emissions and low noise. Coupled with different payloads, it provides solutions for global customers in areas like surveying and mapping, rescue, security & protection, border scouting and forest scouting.

FLIR announces industry's first Multi-Gas Detector

FLIR Systems, Inc. has announced the FLIR MUVE™ C360, the industry's first multi-gas detector specifically built for unmanned aerial systems (UAS).

It will transform how emergency response teams approach chemical, industrial, or environmental incidents by providing a new level of safety, dramatically reducing time to action, and delivering a more complete assessment in situations where every second counts. The C360 is currently compatible with the DJI Matrice 210 UAS platform.

It will allow operators to understand the flow of hazardous vapors both at the source and in the air. It bypasses difficult terrain and enables response teams to quickly draw a perimeter and map known hazards, while preset alarm thresholds help scene commanders or security operators make quick decisions. *www.flir.com*

General Dynamics Mission Systems introduces autonomous unmanned underwater vehicle

General Dynamics Mission Systems has recently released the new Bluefin-12 autonomous unmanned underwater. This new vehicle builds upon the proven Bluefin autonomy and uses shared Bluefin Robotics› core capabilities, increased mission modularity and embedded intelligence to complete users› long endurance, high-consequence and changing missions. The Bluefin-12 may be configured with an optional turnkey survey package delivering integrated survey capabilities including high-resolution sonar, environmental sensing, powerful on-board data processing and highly accurate navigation. *www.generaldynamics.com*

Cyient and QinetiQ Sign MoU to offer avionics products

Cyient had signed a Memorandum of Understanding (MoU) with UK-based defense technology firm, QinetiQ Target Systems (QTS), to offer avionics products for its unmanned target systems. Cyient will provide advanced manufacturing and electronics engineering solutions for QTS' range of unmanned air, land, and sea target systems from its facilities in India. *www.cyient.com.*

Giant XAG defended 20-million-hectare farmlands with crop spraying drones

XAG announces that its Unmanned Aerial System (UAS) crop protection services have covered an accumulated farmland of 20 million hectares, amid a large-scale cotton defoliation operation in Xinjiang, China. Among the first to introduce fully autonomous drones to transform the way crops are grown, XAG has become one of the world's largest agriculture drone manufacturers and service providers. Its crop spraying drones have operated in 38 countries including South Korea, Japan, Australia, Vietnam, Brazil, Mexico, Zambia, etc. *www.xa.com*

Aarav Unmanned Systems' small drone gets DGCA certification

Aarav Unmanned Systems' (AUS) flagship enterprise grade multicopter drone Insight has become the first small category drone to be certified by the Directorate-General of Civil Aviation (DGCA), India.

The DGCA certification is for the 'No-Permission No-Takeoff (NPNT)' and manufacturing compliances laid down by the Civil Aviation Requirement (CAR) for drone operations in India.

At present three other Indian start-ups have been able to obtain certification under micro category. AUS is the first company to get the certification under small category. *www.thehindubusinessline.com*

FAA eases restrictions on drone operations over some federal facilities

The Federal Aviation Administration (FAA) has announced that it is working with other federal agencies to minimize the impact of flight restrictions on drone operators flying near select federal facilities.

The FAA is working with the U.S. Department of Defense to establish intermittent restrictions on drone flights within the lateral boundaries of select federal facilities during specified times. Currently, drone operators are prohibited from flying at these locations at all times. The FAA is working to ensure that these restrictions are narrowly tailored and remain in effect only when necessary.

Notices to Airmen (NOTAMs) will be issued in advance, indicating the sites where these intermittent restrictions will apply. Drone operators will be able to easily identify the status of the airspace at these locations using the FAA's Unmanned Aircraft System UAS Data Display System's (UDDS) interactive map

European Aerial Survey Industry Association launched

Intergeo saw the official introduction of the European Association of Aerial Surveying Industries (EAASI). Aerial survey companies, equipment manufacturers, software developers and service providers from within the aerial surveying industry in Europe were invited to join the newly established association at a reception event held at Intergeo in Stuttgart, Germany.

Similar in concept to MAPPS (the national association of firms in the surveying, spatial data and geographic information systems fields) in the US, EAASI was incorporated in June, followed by the first Association Board meeting. *www.EAASI.eu*

New Quanta Series INS/GNSS by SBG Systems Dedicated to Mobile Mapping

SBG Systems has presented for the first time at the INTERGEO show in Stuttgart (Germany), the Quanta Series, a brand new line of Inertial Navigation Systems (INS) dedicated to air and land based mobile mapping integrators.

Because SBG Systems wants surveyors to save autonomy for additional survey lines, the company has designed a small, lightweight, and low-power inertial navigation system offered on two levels of accuracy. Quanta and Quanta Extra have been developed for compact LiDAR or camera-based mobile mapping solutions. Quanta is designed to provide precise orientation and centimeter level position data delivered both in real-time and post-processing. Embedded in a UAV, this direct geo-referencing solution reduces the need of ground control points and the need of overlapping. Embedded in a car, it ensures a robust trajectory even in harsh urban conditions thanks to an advanced automotive profile with odometer aiding.

Qinertia, SBG's post-processing software, completes the Quanta offer. It gives access to offline RTK corrections from more than 7,000 base stations located in 164 countries. Trajectory and orientation are greatly improved by processing inertial data and raw GNSS observables in forward and backward directions, according to the company. This advanced software also computes your base station position to quickly get your project to centimeter accuracy. Qinertia UAV is offered free for one year when buying a Quanta sensor for a UAV-based mobile mapping solution.

Racelogic introduces the VBOX Touch

The VBOX Touch from Racelogic is the first in a new generation of highly flexible, enhanced accuracy GNSS data-loggers using the very latest technology available. The VBOX Touch comes pre-loaded with a sophisticated performance application. Racelogic will be releasing several additional apps that can be downloaded free of charge, such as tyre temperature monitoring.

The powerful hardware can be used in many types of diverse automotive tests such as acceleration, braking, speed verification, tyre temperature monitoring, lap-timing and durability to name a few. The VBOX Touch comes preloaded with a sophisticated Performance application which covers many common use cases and other applications can be downloaded free of charge from our online library. Racelogic can also write custom scripts based on your own requirements.

The VBOX Touch has a daylight readable colour touchscreen, 10Hz GNSS engine, WiFi, Bluetooth, twin CAN ports, serial port, digital input and four multi-colour LEDs. A high accuracy 2cm RTK GPS version is available, which uses the very latest dual frequency GPS, GLONASS and Galileo signals to deliver class leading accuracy even under difficult conditions. These new signals significantly increase the RTK resilience near trees and tall buildings, providing very precise lap-timing, position triggers and trajectory maps in places where 2cm GPS has never been available before. *www.vboxautomotive.co.uk*

SXblue ToolBox Application on iOS

In these times of mobile technology constant advancement, Geneq (SXblue) remains tuned to the needs of GIS and surveying professionals who work in the field. Following the launch of our Android app a year ago, we are delighted to announce the SXblue ToolBox, the iOS version intended for iOS compatible SXblue devices. The application was developed with special interest to raw data recording and NTRIP service connection.

With the SXblue ToolBox iOS application, the user can analyse the position data provided by the SXblue receiver, as well as location metadata. In addition, the iOS application includes a series of audible and visual alarms that are user-configurable to determine the thresholds of information provided by the SXblue GNSS receiver.

Hemisphere GNSS News

R620 GNSS Receiver

Hemisphere GNSS has introduced the next-generation R620 GNSS receiver, a compact, versatile, and full-featured positioning system. It is a complete refresh of the previous version (R330) and includes an all-new low-profile ruggedized enclosure. With the flexibility and scalability offered within the R620 system, customers can start with sub-meter positioning accuracy and upgrade the receiver (through activations and subscriptions) to add functionality and improve performance capability to centimeter-level accuracy.

The R620 comes equipped with UHF (400 MHz and 900 MHz) radio, cellular modem, Bluetooth, and Wi-Fi, making wireless communications and connectivity easy to use. Ethernet (including Power over Ethernet), CAN, Serial, and USB also elevate the system's capabilities.

S621 GNSS Survey Smart Antenna

The all-new S621 is a complete redesign of the previous generation version (S321+) and offers added benefits and value to an already impressive range of features and functionality.

Powered by the all-new Phantom™ 40 GNSS OEM board, the S621 survey smart antenna processes and supports over 800 channels with flexible and scalable simultaneous tracking of every modern and planned GNSS constellation and signal including GPS, GLONASS, BeiDou (including Phase 3), Galileo, QZSS, IRNSS, SBAS, and Atlas® L-band. The Phantom 40 GNSS OEM board is powered by Hemisphere's recently announced next-generation Lyra™ II digital ASIC, Aquila™ wideband RF ASIC, and Cygnus™ interference mitigation technology. *www.hgnss.com*

Iridium and OneWeb to Collaborate on a Global Satellite Services Offering

Communications Inc. and OneWeb have announced they have entered into a MoU to work together toward a combined service offering. This combined service offering would be designed to make it easier for their mutual partners to offer unique bundling and co-marketing opportunities for the Iridium Certus® L-band services and OneWeb's Ku-band service. The offering would leverage the strengths of their respective low-Earth-orbit (LEO) networks. This is the first time that LEO operators have collaborated to deliver services in L-band and Ku-band.

The MoU also creates opportunities for companies that manufacture both OneWeb and Iridium CertusTM terminals. Such new options could include Iridium-OneWeb companion packages in addition to providers being able to offer combined equipment or even new dual-constellation terminals. *www.oneweb.world*

IFEN's New NCS NOVA GNSS Simulator

IFEN GmbH has launched its new NCS NOVA GNSS Simulator, which is a high-end, powerful, but easy to use satellite navigation testing and R&D device. It is fully capable of multi- constellation and multi-frequency simulations for a wide range of GNSS applications. The NCS NOVA GNSS Simulator is one of the leading solutions on the market providing almost all relevant GNSS frequencies in one box.

Due to the modern and flexible software defined radio (SDR) design of this simulator, testing requirements will be met with the minimum of equipment, facilitating logistics and reducing the cost of ownership. The innovative multi-constellation and multi-frequency simulation capability sets new standards in the field of GNSS simulation in terms of fidelity, performance, accuracy and reliability. Designed to deliver maximum flexibility, users are no longer faced with configuration limitations.

Wabtec to deploy Septentrio GPS receivers

Wabtec is implementing Septentrio GNSS receivers in its GoLINC™ Edge platform, providing positioning, connectivity, data storage and enhancing Positive Train Control (PTC) with the adoption of even higher-precision positioning technology. Two GNSS receivers are being installed on each locomotive to provide precise positioning information as part of the GoLINC system. Septentrio receivers are also being installed as position reference modules along 30,000 miles of track. *www.WabtecCorp.com*

AllSource Analysis wins NGA contract

AllSource Analysis Inc. (AllSource) has been awarded a $1.956 million contract by the National Geospatial-Intelligence Agency (NGA). The one-year contract supports the NGA's Anything-as-a-Service (XaaS) program. Based in Longmont, Colo., AllSource is providing a cost-effective and integrated approach to develop military-related GEOINT data sets specifically for North Korea. The NGA project leverages AllSource's expertise in analyzing remote sensing imagery and other geospatial data to detect specific types of objects and report on changes in features and patterns. *www.allsourceanalysis.com*

GSS9000 Series GNSS Constellation Simulator by Spirent

Spirent Communications plc has announced the launch of its enhanced GSS9000 Series GNSS constellation simulator. Providing significantly-improved capability, flexibility and performance, the GSS9000 Series has been updated to meet the ever-more-demanding test needs of high-performance satellite navigation systems. It addresses this need by doubling the number of supported channels (320 in a single chassis) while maintaining its full performance specification, including in key areas such as signal iteration rate and low latency, under maximum signal dynamics. These attributes, together with the ability to produce a comprehensive range of emulated multi-GNSS, multi-frequency RF signals, enables full and future-proofed testing of advanced applications.

It also features sophisticated spoofing test capabilities, with full parametric control of multi-copy constellations, and trajectory spoofing/meaconing. Precise phase-aligned signal wavefront generation and multi-antenna/output capability is supported, creating the most capable anti-jam and anti-spoof test system available anywhere. *www.spirent.com*.

NavVis IndoorViewer 2.5

NavVis has announced the beta release of NavVis IndoorViewer 2.5. This major software release will significantly extend the point cloud functionality through a new download feature that lets users select and crop sections of large point cloud files in browser, and then download and use the file in third party modeling software. NavVis IndoorViewer is a web-based 3D building visualization software that displays point clouds, 360° panoramic images and floorplans as realistic, fully immersive digital buildings. *www.navvis.com*

Breakthrough software-based Cybersecurity Solution

Regulus Cyber has introduced a breakthrough software-only cybersecurity solution designed to protect GNSS from spoofing attacks. The new Regulus Pyramid GNSS is the industry's first stand-alone software solution that doesn't require any additional hardware to protect a GPS receiver or Chipsets - ensuring the security and reliability that are essential to safe and accurate navigation across a wide range of applications including automotive, mobile, aviation, maritime and critical infrastructure. *www.regulus.com*

PCTEL unveil GNSS L1/L2/ L5 Combo Antenna

PCTEL, Inc. has announced an innovative new antenna that combines precision multi-constellation GNSS with high performance LTE, sub-6 GHz 5G, Bluetooth, and WiFi connectivity. The Coach™ II antenna with GNSS L1/L2/L5 is designed to provide greater precision and reliability for advanced rail communications systems, enabling everything from next-generation Positive Train Control (PTC) to passenger WiFi. *www.pctel.com*

Europe-wide High Precision GNSS Positioning business by Mitsubishi Electric

Mitsubishi Electric Europe B.V. has established the High Precision Positioning Systems Division at its German Branch headquarters in Ratingen, Germany. The new division offers key technologies to German and European customers to accelerate the introduction of centimeter-level autonomous driving and safe driving assistance. *www.MitsubishiElectric.com*

GMCA Bulgaria selected CHCNAV i80

Terralang Ltd., the authorized CHCNAV reseller in Bulgaria delivered to the Geodesy, Mapping and Cadaster Agency (GMCA) 30 sets of i80 GNSS equipment in both base and rover configurations. The GMCA is a Bulgarian government institution responsible for civil surveying and mapping, as well as for all cadastral works in the country.

Trimble News

Trimble Pivot Platform and Alloy GNSS Reference Receiver

Trimble has announced new capabilities to its Real-Time Network (RTN) portfolio—the Trimble® Pivot™ Platform and the Trimble Alloy™ GNSS reference receiver—that will enable operators to continue to meet the ongoing demand from surveyors, mapping professionals and precision farmers for accurate, reliable corrections derived from real-time networks. A well-established network software, Trimble's Pivot Platform manages and controls small, mid-size and countrywide GNSS networks.

Trimble SiteVision

Trimble has introduced its Trimble® SiteVision™ system, an outdoor augmented reality (AR) solution that enables users to visualize 2D and 3D data on virtually any project site with cellular or internet connectivity for easier and more efficient planning, collaboration and reporting. Combining hardware and software in an integrated, lightweight handheld or pole-mounted solution, users can view 3D models and assets in a real-world environment at a 1:1 scale, from any angle or position. *www.trimble.com*

X7 3D Laser Scanning System

Trimble® X7 3D laser scanning system, enables professionals of all scanning levels to quickly and easily capture precise 3D scanning data to produce high-quality deliverables. The compact and reliable laser scanner comes with a Microsoft® Windows®-based Trimble T10 ruggedized tablet for control and project visibility, along with a backpack and lightweight tripod for portability. It is fully integrated with the new Trimble Perspective software specifically designed for in-field control and complete registration.

Bundled with the HCE320 controller, the LandStar7 mobile software, and the CGO 2 post-processing software, this solution offers the ability to perform GMCA control activities at a high technology level. After extensive commercial and technical evaluations, the CHCNAV solution was selected and the tender awarded to Terralang, *www.chcnav.com*

QinetiQ secures £67m contract

QinetiQ has won a £67m contract with the Ministry of Defence (MOD) Defence Equipment and Support (DE&S) to develop multi-constellation satellite receivers under the UK Robust Global Navigation System (R-GNS) programme.

The programme will deliver critical capability to provide UK Defence with accurate and resilient positioning, navigation and timing (PNT) which will underpin the UK's ability to undertake 24/7 military operations around the world in the most demanding and increasingly contested operational environments.

NovAtel® added as positioning intelligence supplier to CNH Industrial

NovAtel Inc. Has announced that it will supply its positioning intelligence technologies to CNH Industrial N.V. This introduces NovAtel's agriculture-focused GNSS receivers and Correction Services to the CNH Industrial global agricultural brands Case IH and New Holland Agriculture, together with European brand STEYR.

The addition reflects the enduring reputation for quality, exceptional service as well as robust and reliable positioning intelligence solutions that NovAtel has provided to the agriculture market for the last 19 years. *novatel.com*

The ZEB Discovery is launched

The ZEB Discovery is capable of rapidly capturing intricate data with the use of industry-leading SLAM (simultaneous localisation and mapping) technology and NCTech's iSTAR Pulsar panoramic camera for ultra-high definition image capture.

The end to end solution automatically synchronises the point cloud with imagery for a unique walk through of the area of data captured. Combining the two data sources into one view brings a new way to visualise reality for a wide variety of occupations – from surveyors to environmentalists. *https://geoslam.com*

OxTS launches the next-generation RT

The next-generation RTs feature a range of improvements and innovations that that make them easier to setup and use. Upgraded processing hardware and a new Novatel OEM7720 receiver boost the next-gen RT's core functionality, while a host of new connectivity options and built-in features that simplify configuration and data extraction.

Key to the enhanced ease of use of the new RT3000 v3 is the integration of the RT-Range Hunter processing engine, turning the RT device itself into a single-box solution for ADAS testing. *www.oxts.com*

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October 2019

Commercial UAV Expo Americas
28 - 30 October
Las Vegas, USA
www.expouav.com

ISGNSS 2019
29 October - 1 November
Jeju Island, South Korea
www.ipnt.or.kr/isgnss2019

November 2019

International Timing and Sync Forum 2019
4-7 November
Brighton, United Kingdom
http://itsf2019.executiveindustryevents.com

GEO Week 2019 and the GEO Ministerial Summit
4-9 November
Canberra, Australia
www.earthobservations.org

The Commercial UAV Show 2019
12 – 13 November
London, UK
www.terrapinn.com

International Navigation Conference 2019
18 - 21 November
Edinburgh, Scotland
https://rin.org.uk/events

December 2019

Amsterdam Drone Week
4-6 December 2019
Amsterdam, The Netherlands
www.amsterdamdroneweek.com

International Committee on Global Navigation Satellite Systems (ICG)
8 - 13 December
Bengaluru, India
www.icg14.org

39th INCA International Congress
18 – 20 December
Dehrardun, India
http://inca2019.org

January 2020

International Workshop on Advanced Spatial Analytics and Deep Learning for Geospatial Applications
20 - 31 January
Bengaluru, India
www.workshop.csag.res.in

Precise Time and Time Interval Meeting (PTTI)
21 - 24 January
San Diego, USA
www.ion.org

March 2020

Munich Satellite Navigation Summit
16 - 18 March
Munich, Germany
www.munich-satellite-navigation-summit.org

10th International Conference and Exhibition on Geospatial & Remote Sensing (IGRSM 2020)
17 -18 March
Kuala Lumpur, Malaysia
http://igrsm.org/igrsm2020

April 2020

SpaceTimeAI 2020
20 - 22 April
London, UK
www.ucl.ac.uk/civil-environmental-geomatic-engineering/

May 2020

GISTAM 2020
7-9 May
Prague, Czech Republic
www.gistam.org

FIG Working Week 2020
10 -14 May
Amsterdam, the Netherlands
www.fig.net

European Navigation Conference 2020
11-14 May
Dresden, Germany
www.dgon.de

GeoBusiness 2020
20 - 21 May
London, UK
www.geobusinessshow.com

ICCM 2020: International Conference on Cartography and Mapping
21 - 22 May
London, UK
https://waset.org

June2020

XXIVth ISPRS Congress
14 - 20 June 2020
Nice, France
www.isprs2020-nice.com

July 2020

GI Forum
7 - 10 July
Salzburg, Austria
www.gi-forum.org

Esri User Conference
13 - 17 July
San Diego, USA
www.esri.com

September 2020

ION GNSS+ 2020
21-25, September
St. Louis, Missouri, USA
www.ion.org

October 2020

INTERGEO 2020
13 – 15 October
Berlin, Germany
www.intergeo.de


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