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THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

Land Administration and Geospatial Information

HARD TALK

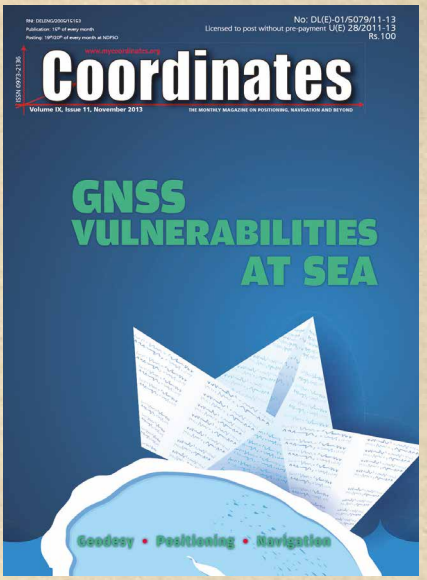
A Critical Evaluation

By: Dr. Anthony Beck | Vladimir V. Evtimov | Dr. Keith Clifford Bell

Understanding the RINEX format for GNSS data transfer and storage

In Coordinates

10 years before...



mycoordinates.org/vol-9-issue-11-November-2013

Multi-GNSS positioning campaign in South-East Asia

Tung Hai Ta, Duc Minh Truong, Tu Thanh Thi Nguyen, Hieu Trung Tran and Thuan Dinh Nguyen: NAVIS Centre, Hanoi University of Science and Technology, Vietnam

This paper has presented the positioning results of the existing and also the recently launched Global Navigation Satellites Systems including GPS, GLONASS, Galileo and Beidou. More importantly, the paper has proved that the multi-GNSS positioning in the South East Asia region is possible and its performance is outperform the stand-alone ones in terms of positioning accuracy, availability and reliability.

A solution to map project area lying in two UTM zones

Suddhasheel Ghosh
Department of Civil Engineering, MGM's Jawaharlal Nehru Engineering College, Aurangabad, Maharashtra, India

Bharat Lohani
Department of Civil Engineering, Indian Institute of Technology, Kanpur, Uttar Pradesh, India

Ajay Dashora
Department of Civil Engineering, Indian Institute of Technology, Kanpur, Uttar Pradesh, India

Currently, the Universal Transverse Mercator (UTM) projection system is the most popular system for making maps or executing projects in combination with the WGS84 datum. Survey of India has also started generating a public series of maps in this popular combination, in order to comply with the need for standards.

Do more satellites lead to a better integrity performance

Michael Mink and Julian Daubrawa Astrium GmbH, Ottobrunn, Germany

The outcome of the assessment performed in this paper is to demonstrate that simply using all satellites that are available in sight of the user does not always lead to optimal integrity performance. However as hundreds of subset combinations are possible depending on the number of satellites available it is deemed that a very high computational load is needed at user side. To avoid computing all possible subset combinations an intelligent selection of the subsets that are taken into account can be chosen.

GNSS Vulnerabilities at sea

Chaz Dixon
MD, Navigation Unlimited
Head, Position Navigation and Timing, Satellite Applications Catapult Chair, Satellite Navigation Special Interest Group, Royal Institute of Navigation, United Kingdom

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Spirent Communications plc, United Kingdom

Andrew Hart
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General Lighthouse Authorities of United Kingdom and Irelan

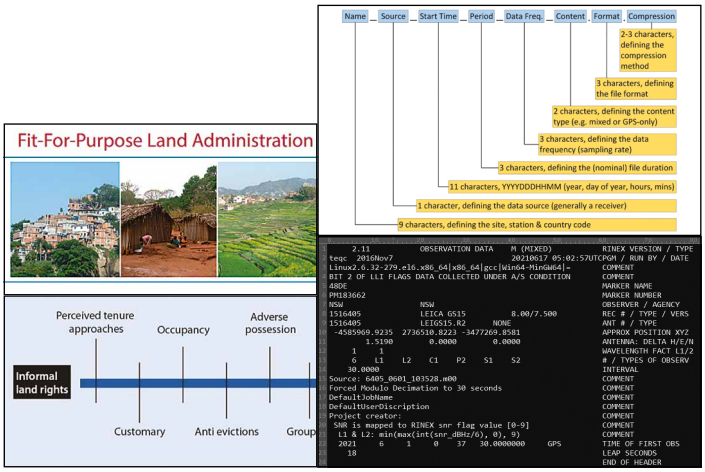
George Shaw
General Lighthouse Authorities of United Kingdom and Ireland

Chris Hill
University of Nottingham, United Kingdom

Steve Hill
Technical Director, CBIL, United Kingdom

Colin Beatty
Managing Director, CBIL, United Kingdom

The paper reports from the STAVOG study that examined two major threats and vulnerabilities of GNSS, namely jamming and severe ionospheric disturbance. In this paper due to space constraints we report only on the jamming analyses. We examine how jamming impacts GNSS receiver function and performance, and quantifies that impact particularly for operational use by SOLAS (Safety of Life at Sea) marine users.



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Editor Bal Krishna
Owner Coordinates Media Pvt Ltd (CMPL)

This issue of Coordinates is of 36 pages, including cover.

Humanity

As the world rages with debate,

About who is right,

And whose rights are endangered,

There unfolds a 'humanitarian catastrophe'…

The death toll is mounting…

Where even babies have become most unfortunate victims,

Who are symbols of hope and happiness,

Who don't and can't take sides.

Humanity is paramount…

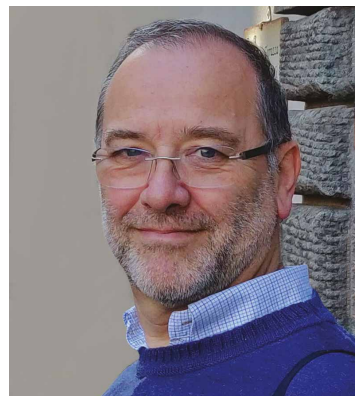
It must prevail!

Bal Krishna, Editor
bal@mycoordinates.org

Land Administration and Geospatial Information Hard Talk: A Critical Evaluation

Coordinates is pleased to publish this interview of three world experts, on critical issues concerning land administration and geospatial information. Dr. Anthony Beck, Vladimir V. Evtimov and Dr. Keith Clifford Bell, whose collective experience amounts to almost one century, provide a striking candor as they convey their respective deep knowledge and understanding to respond to Coordinates' deep-dive questions. This special interview is a hallmark of truth to power in addressing the often-contentious topics spanned by the far-reaching land administration and geospatial information disciplines.

Dr. Anthony Beck
An independent consultant who specialises in digital transformation using the Land Administration Domain Model (LADM), formerly with Registers of Scotland and Ordnance Survey International.



Vladimir V. Evtimov
Land Tenure Officer with the Food and Agriculture Organization (FAO), a land professional experienced in land reforms and land administration.

Dr. Keith Clifford Bell
International Development Consultant for Land, Geospatial Information and Disaster Resilience (freelance); Industry Advisor to The University of Melbourne Center for Spatial Data Infrastructures and Land Administration; Formerly staff of the World Bank, Surveyor-General of the Australian State of Victoria and senior public sector manager in various roles in Australia including national mapping, NSDI and Territory land administration.

1. To set the scene for this interview, could each briefly outline your background?

Anthony Beck: I am a geospatial and data professional. I spent a number of years in academia working on utility, smart city, remote sensing, environmental and heritage projects. This included the development of the technology infrastructure behind award winning utility data integration projects in Scotland and England. I then transitioned to industry, predominantly working on digital transformation projects. I started my Land Administration journey at Registers of Scotland: I supported the digital transformation processes in response to the 2012 legislation reform. This included the conceptual alignment of Scots legislation and registration practice with the Land Administration Domain Model (LADM) and other standards. I then moved to Ordnance Survey International where I supported their global activities. This included specialist consultancy services to support the implementation of a new Land Register platform and associated operational capability in Saudi Arabia. I supported the alignment of operational and digital approaches against the published regulations, proposed the strategy for data quality verification and enhancement and provided a best-practice overview for parcel-based cadastres.

I am now an independent consultant with specific interests in land transactions, automation, legal integration, implementation patterns and ontologies. I take a standards-based approach that aims to include legal, policy and practice perspectives. I also provide advice and feedback to British Standards Institute (BSI) and International Standards Organisation (ISO) in respect of the revision to the LADM (ISO19152).

Vladimir V. Evtimov: A land professional experienced in land reforms, modernising land administration and geospatial information systems in many transitional and developing countries across all regions, I hold a MScEng (hons.) in geodesy, photogrammetry and cartography (1986), and a real property valuation license (1994) in my native Bulgaria. Collaborating with key global development partners in the land sector since 1991, I provide technical advice to government investments in land reforms and building institutional capacity of national land/geospatial agencies. As of 2004, I work for the Food and Agriculture Organization (FAO) as a Land Tenure Officer. I was part of the FAO core team which supported the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (2012) often referred to as the VGGT. My recent sideline is GeoTech4Tenure[1] – a joint IFAD[2]- FAO capacity development initiative for improving tenure security of development investment beneficiaries by combining inclusive, participatory methodologies with geomatics and Information and Communication Technology (ICT).

Keith Clifford Bell: I am probably best known through my service as staff at the World Bank, 2003-21, where I led the land and geospatial program in the East Asia Pacific Region until 2017. I also led and/or advised on post-disaster reconstruction projects in several locations including Aceh and North Sumatra 2005-10, Haiti 2010-1, Philippines-Leyte (Tacloban) after the super-typhoon Yolanda/Haiyan in 2013, and also in Nepal 2018-20. Following my time at the World Bank, I worked in Saudi Arabia, based in Riyadh for over a year 2021-22, for the Public Investment Fund as the Strategic Advisor, and subject matter expert for Land Registration and Geospatial. Prior to joining the World Bank, in my home country Australia, I served as Surveyor-General of the State of Victoria, General Manager of Land in the Australian Capital Territory and I worked in various senior national roles with the Australian Surveying and Land Information Group (now Geoscience Australia) leading national mapping programs and NSDI development. In my earlier days, as a licensed surveyor I worked in cadastral, engineering, and hydrographic surveying, and as a civil engineer I worked in port development and construction, dredging, infrastructure and airport development. I have also maintained a parallel career in the Australian Army, which I joined as a recruit immediately after high school and subsequently continuing as a senior officer in the Reserve. My journey continues as a strategic development consultant, an industry adviser to the University of Melbourne's Center for Spatial Data Infrastructures and Land Administration (CSDILA) and Army. There has never been a dull moment.

2. How do you see the role of surveying in solving the issues of Land Administration? How has it changed over the past two-three decades? Where do geospatial specialists/scientists fit in?

AB: Change will remain a constant. The Land Administration ecosystems will become digital. These digital systems will become data driven. By efficiently sharing and re-using authoritatve data a resilient ecosystem is created. An interconnected network of linked data should lead to better decision making across the ecosystem and provide a platform for innovation. Citizens should

> "Land Administration should not be uncritically led by technological development. The challenge is to align technological development with standards, knowledge, the legislative need, the operational capability and most importantly the social context." – *Anthony Beck*

benefit from improved data quality and service innovations. Regulators will adapt their processes as the systems mature and the changes in regulatory and policy need become apparent. The roles of surveyors, analysts, geospatial scientists and other key stakeholders will evolve accordingly. This will go hand in hand with changes to implementation and so-called best-practice frameworks e.g. Land Governance Assessment Framework (LGAF), Integrated Geospatial Information Framework (IGIF), and Framework for Effective Land Administration (FELA). It is likely that cadastral surveyors will continue to focus on data collection, interpretation, validation and application, while geospatial scientists will focus on reuse and integration. It is also likely that aspects of data collection and reuse will become more specialised. This will include ensuring that the ecosystem can expose indicators and metrics to support monitoring programmes.

VVE: Surveying is a foundational profession underlying land governance from the outset of human civilization. A few millennia later, land surveyors – *géomètres* – still meticulously measure space-time to capture data and model our reality, pioneering innovative technologies and inclusive, participatory processes in a constant endeavour for refined, equitable land governance, tenure security, socio-economic and environmental resilience – naturally within the paradigm of land management and land administration. The past couple of decades witness a peculiar *democratisation* of state-of-the-art geomatics tools for land administration: today, a much wider array of non- professionals can use affordable land survey instruments, remote sensors or tools, allowing even to *crowdsource* some geospatial information collection. Professional land surveyors, however, remain and will remain the *synergists* of land management and land administration efforts by various other professions, – like land lawyers, ICT experts, Geographic Information Systems (GIS) specialists, land valuers, planners, developers, public administrators – since they have the unique skillset to synergistically integrate all their inputs into effective and efficient land administration and geospatial ecosystems.

KCB: Surveyors undertake critical roles in land administration and it's far more than measurement, demarcation and the spatial elements of the cadastre. In many jurisdictions, cadastral surveying is regulated with licensing or registration of surveyors. Surveyors collect evidence of occupation and interpret the evidence, which includes measurements. Surveyors must ensure the relevant laws, regulations and standards are followed to ensure rights are correctly recorded and registered by the land registration authority. Further, surveyors may be called upon to appear in courts to provide evidence in land and boundary disputes.

A lot has changed over the past decades with new technologies which have improved measurement and positioning. Theodolites and steel bands have given way to total stations, Global Navigation Satellite System-Continuously Operating Reference Station (GNSS-CORS), drone-based platforms for imagery acquisition and so forth. The digital ecosystem has become more pervasive with electronic lodgement of plans, online access to the cadastre and e-conveyancing. Updates to the cadastre are more frequent and closer to real time and overall spatial accuracy is higher. But surveyors have a far broader role in cadastres than just measurement. In common law countries, and also many civil law countries, under the well-accepted hierarchy of cadastral evidence, measurement or geospatial carries the least weight. It is the evidence of intention which carries the highest weight and that is usually defined by natural boundaries and human-placed boundary markers and borders. Surveyors are usually regulated and have greater accountability and liability, so professional indemnity is now even more important. Finally, surveyors spend quite a bit of their time in the field and do engage with land occupants as they go about their work.

There are most definitely roles for geospatial scientists especially in value-adding to cadastral data, analyses and applications, and these are predominantly office-based tasks and not directly dealing with the people on the land. Geospatial scientists are commonly not professionally regulated. As we increasingly see the digital ecosystem for land administration emerging, geospatial specialists will most definitely have increasing roles to play, and especially in emerging areas like 3D and Digital Twin.

3. As you have a lot of experience in this domain, would you like to highlight the key differences in terms of approach and status in land administration in developed countries and developing countries?

VVE: Based on my observations and professional experience, the levels of socio-economic development and geospatial maturity of an economy are strongly interdependent and closely correlated. Land Administration (LA) – as vital pillar of geospatial maturity – in developed countries is characterised by fit-for-purpose, flexible approaches and technology, while transitional or developing economies often follow ossified approaches and prescribed, dated technology. Thus, Land Administration Systems (LAS) in developed countries are mostly service oriented, accessible, accurate, interoperable, affordable, effective and efficient, in contrast to transitional or developing economies where LAS are often characterised by red tape, inaccessible, slow, costly, outdated, impractical and inefficient. Of course, there are wonderful exceptions from this general trend, particularly in some isolated customary and Indigenous Peoples' communities, but these exceptions do not refer to high levels of socio-economic development, and only confirm the need for fit-for-purpose approaches and technology. LAS in developed economies resulted from years on end of purposeful, focused efforts, trials and errors, – and everything achieved by hard efforts requires further efforts to be maintained. If the efforts wane, the achievement

falls apart. The mentality of constant LA and geospatial systems maintenance is often uncommon in transitional and developing economies, – thus failing otherwise excellent achievements of LAS development projects. In a country where LAS modernisation is ongoing, the head of the national mapping agency, which is also in charge for land administration, shared that there had been already two prior donor-funded projects to successfully develop an automated Land Information System (LIS) supporting the LAS. The agency had twice slipped back to paper-and-pencil technology immediately after the donor left and the financial support ceased. Luckily, there was the back-up of paper-and-pencil technology, otherwise the land administration services in the country would have had collapsed. A positive maintenance culture, – looking at LA and geospatial systems as crucial infrastructure for sustainable development and resilience, – is an asset which is frequently missing in developing and transitional societies. Shifting mentality takes time, and is usually a matter of bringing up and educating a new generation of LAS professionals and managers. Continued support by foreign development partners, peace and stability may help to bring up the LA capacity and mentality required in transitional and developing economies.

KCB: I think it is always important to be aware of, and understand, the political economy of developing countries when considering support for investment in land administration. Every country is unique, and there can even be significant differences at sub-national level. Arguably, we live in a "two-speed world", a term I believe was first raised at the 2013 World Bank Land and Poverty Conference, distinguishing between developed and developing countries and economies. Developing countries often lack technical capacity for undertaking land administration reform, development and implementation. Such capacity limitations may also be experienced in developed countries. All too often, they lack funding, both for normal institutional operations and development investment, and seek donor support, for which they are then obligated to adhere to donor obligations and reporting. Further, in many developing countries governance is a significant issue. One thing I have usually observed in developing countries is decentralization of land administration from provincial to district and sub-district levels. Stable power (electricity) and access to communication connectivity can be key limiting factors in developing countries, especially in remote locations. In many developed countries, land administration may be more centralized and as online services are more widely adopted, people may be less likely to visit an office. So, being mindful of the aforesaid factors will contribute to the approach to land administration support in developing countries. Many developing countries experience conflict and/or political instability. At the present time, there are around 32 of the world's countries experiencing conflict, which equates to more than 15 percent of all countries.

> "If data are not used to improve overall decision making, governance and people's lives, the investments in acquisition, processing, analyses, storage, maintenance, providing access, and so forth are largely wasted."
>
> *– Keith Clifford Bell*

4. In your experience, how effectively have ICT and geospatial technologies been used for land administration? Would you like to share any or some success stories? Have there been any examples of failures?

AB: I would like to address this question from the perspective of future expectations associated with integrating data across the ecosystem. Technology has significantly disrupted Land Administration over the past few decades. This will continue. New sensors and improved data extraction and integration frameworks will continue to redefine the art-of-the-possible. However, Land Administration should not be uncritically led by technological development. The challenge is to align technological development with standards, knowledge, the legislative need, the operational capability and most importantly the social context.

Loosely coupled integration allows bespoke views to be built over the different data resources. This may, for example, allow data from utilities, building regulations, cadastre, thermal modelling, and building sensor to be aggregated at a property level to produce a bespoke 'digital twin'. While the integration of such data will provide new opportunities it will also present new risks. It is critical that data ethics and privacy issues are duly considered. This is particularly relevant for Machine Learning approaches: the non-deterministic nature of generative Large Language Models means that the same inputs can result in different outputs. This has ethical implications. It also has potential legal implications if the results can neither be replicated or justified in a dispute.

Digital transformation involves change across a wide range of areas. By focusing on technology, we may lose sight of the companion changes required in other areas. Moving to an integrated ecosystem requires social, organisation and legal as well as technological change.

VVE: ICT and geomatics are now at the heart of modern LAS, even though their application is not a silver bullet as they do not guarantee inclusion, equality or efficiency.[3] LA and geospatial systems are critical for sustainable development and their digitalization has rationally

no alternative, – they are an integral building block of e-governance. However, digitalized LA systems should offer options for analogue paper-and-pencil service delivery to avoid risks of exclusion or marginalization of vulnerable groups. I have seen both success stories and failures in modernising LAS. For example, the establishment of a modern LAS in Kyrgyzstan (2002-2014) was a success, in my view, due to the incremental in-house development of fit-for-purpose ICT and Land Information System (LIS) in support of LA, combined with strong political will and national ownership on the reforms. In other transitional economies there were failures by leading global ICT service providers to deliver tailored LIS in support of the local LA practices, mostly due to shortage of political will and poor national ownership on the LA reforms, presumptuous ambitions of development partners, lack of maintenance culture, no viable mechanism to trigger updates, no habituation of local communities to use the formal LAS, and ignoring the LA specificities and traditions in the target jurisdiction.

KCB: I have seen successes especially in terms of digitalization of land registries (digitization of records and computerization of systems and processes) and the application of digital orthro-rectified imagery to support the cadastral mapping bases across East, South and Central Asia. The innovations with geospatial technologies in Türkiye were especially profound, particularly in 3D visualization. I understand that a new World Bank investment project in Digital Twin is pending and very much look forward to its success.

On failures, perhaps the most extreme failures I saw were in Afghanistan – and well before the Taliban retook power in 2021. Notably, the three significant and separate project failures that I came across did not involve World Bank support. The failures I speak of were not due to the Afghans, rather due to the donor, especially regarding project design and implementation oversight, or supervision as it is often called. Firstly, a major investment in a CORS network failed within 6 months due to the donor giving little to no consideration to capacity building, security and stable, continuous power, amongst others. Secondly, the Land Titling and Economic Restructuring in Afghanistan (LTERA) Program, 2004-09, with an investment of around US $46 million, reported to be a huge success in improving property rights for millions of Afghans and resolving land rights disputes through formalized property rights by establishing clear documentation and transfer of land ownership – this was simply not true. Thirdly, the Land Administration Reform Afghanistan (LARA) Project, 2011-2014, saw around US$42 million expended with little delivered, which was reported as a great success – this was also not true. I was shocked with what I witnessed in my first mission to Afghanistan in June 2013. We found vast quantities of unopened boxes of equipment in Kabul, software not installed, poor facilities and training allegedly provided was overstated and under-delivered. An independent review was commissioned where concerns and failings were confirmed and backed by strong evidence. Investigations by the US's own Office of the Special Inspector General for Afghanistan Reconstruction (SIGAR) were especially critical of support in these areas.[4,5] But, perhaps more importantly, the then newly created Afghan Land Authority (ARAZI) was highly critical, and it was initially left without donor support largely due to the widely held perception that it had already developed great capacity and was well-equipped. Fortunately, funds from the Multi-donor Trust Fund, administered by the World Bank, were made available to help address a number of the deficiencies and together with support from Türkiye enabling a new investment in land administration to be prepared. There will always be failures in project implementation, but these three experiences in Afghanistan saw significant less than effective investment, in ICT and geospatial technology as well as broader capacity development and land administration reform. Unfortunately, the donor's reliance on largely unchecked lead contractors, under which was Technical Assistance (TA), was a huge mistake. Of course, the country was in conflict and so all personnel were at risk. Sadly, the examples of Afghanistan, are not unique as I have witnessed over the past almost two decades. Fortunately, as I have observed, such extreme failures are not common.

5. How do you view the role of technologies like Internet of Things (IOT) Unmanned Aerial Vehicle (UAV, drone) Artificial Intelligence (AI) Laser imaging, Detection and Ranging (LiDAR) in Land Administration?

AB: There's a mixed bag of technologies in the list. New remote sensing sensors deployed on a range of different platforms will continue to deliver metric survey outputs in 2, 3 and 4 dimensions. However, multispectral, hyperspectral and dedicated thermal sensors allow the extraction of a multitude of data themes that impact on the range of Land Administration activities. Machine Learning will supplement traditional classification techniques and support extraction of novel data which can improve current decision-making frameworks. The Internet of Things (IOT) provides massive amounts of data from spatially located sensors. All this information needs integrating in a co-ordinating platform to support exploratory analysis, policy and decision making.

VVE: I believe that land surveyors inherently utilise drones, LiDAR and AI for topographic and cadastre mapping and updating, as well as for 3D modelling our reality, and thus these technologies have direct impact on refining LA and geospatial services. Further, IOT has a constantly growing role, – particularly in the context of 3D and Digital Twin City modelling, – offering major land management, resilience and disaster management innovations. Piloting such technologies in land administration and land management in countries where I work, like Guyana, Türkiye, Kenya, Bangladesh, shows great promise. In this vein, the future will see more 3D cadastre initiatives emerging.

"PPP for LR services is highly risky, and should be applied only when there are efficient and rigid safeguards, including strong regulation, in place, – which is hard to achieve." – *Vladimir V. Evtimov*

KCB: The role of technologies is very important, cross-cutting and far-reaching. Technologies using location-based services, drones and autonomous vehicles, 3D modelling, robotics, artificial intelligence, machine learning, virtual reality, Big Data and the Internet of Things are impacting both land administration and geospatial. It's a combination of both foundational and disruptive technologies. Increasingly we will see land administration in many jurisdictions embracing a digital ecosystem which will have impacts on privacy and identity. Every day we hear mind-numbing statistics about the amount of data that's being produced. Also, every day the hype-spin about the value that data-driven decision-making can bring is thrust on us. So, for both government and business, there must be a continued focus on improving data acquisition, processing and management. But it goes beyond that. So, I would like to raise the further topic of what is termed "Datafication" – a term being used to describe the phenomenon of many aspects of life being turned into data on a huge scale and then realized as some new form of value, for example, through predictive analytics. If data are not used to improve overall decision making, governance and people's lives, the investments in acquisition, processing, analyses, storage, maintenance, providing access, and so forth are largely wasted.

6. Recently, a lot has been talked about the role of blockchain technology in land administration. What is your view about it? Is it the best alternative?

AB: I am wary of the utility of blockchain in Land Administration and especially wary of it in Land Registration. Blockchain is an intrinsically digital solution and implies a fully digital environment. This is rarely the case. At its heart blockchain is a ledger-based system which creates an immutable cryptographic hash for each transaction. This makes it relevant for deeds-based registration systems where each deed represents a transactional change to a register. However, this can make blockchain less relevant for Titling systems which represents 'state' rather than 'state change'. It is often argued that blockchain provides transparent transactions that remove the need for an intermediary. I would argue that this depends on the nature of the `thing` being transacted. For banking transactions, the granter and grantee tend to have a complete, or near complete, understanding of the implications of the transaction. However, the same is not true for land. Rights are complex. Overriding interests, restrictions and responsibilities, and other obligations may not all be stored on the land register. The new owner may not understand what these rights mean. It is important that the rights implications of a land transaction are clearly understood. This is likely to mean involving a legal intermediary. Land is not money and what may work in one context may be inappropriate in another. In summary, blockchain technology is not a substitute for good land policies and institutions - it has too many shortcomings. However, where the circumstances are appropriate blockchain can complement and support them. Blockchain is definitely not a 'silver bullet'.

VVE: My empirical knowledge of attempts to use blockchain in LA indicates that the technology does not meet basic requirements of LIS supporting LA, and there are better fit-for-purpose LA database management solutions. Generally, experienced LA professionals voice healthy scepticism about using blockchain in LA.[6] In my professional work, blockchain is completely unrealistic for LAS in transitional and developing countries due to its demanding prerequisites like full digitization of LA records and fundamental government registers. Therefore, one should be able to critically assess the applicability and sustainability of proposed digital technologies and separate hype from reality.

KCB: I will be very blunt. Blockchain remains on the Gartner Hype Cycle at the Peak of Inflated Expectations[7]. I have seen multiple examples over the past 6-7 years of FinTechs lobbying governments and making bold claims, all of which have turned out to be hype-spin. To be frank, all too often, purveyors of blockchain, are pushing a solution for a problem that either does not exist or has not been defined. I have also found that almost all reported blockchain implementation for land registration is actually pilot testing rather than actual implementation, and much of the reporting is by FinTechs rather than the government.

In that vein, I would refer readers to two excellent publications concerning blockchain, which provide good insights on how to determine whether a blockchain solution may be suitable for your needs: "Blockchain Technology Overview" published in 2018 by the US National Institute of Standards and Technology[8] and "Blockchain Beyond the Hype: A Practical Framework for Business Leaders" published in 2018 by the World Economic Forum.[9] In particular, the WEF paper provides a decision-tree tool which is intended to enable rapid initial analysis of whether blockchain is an appropriate solution for a defined problem. The tool has more than 12 steps (boxes) which require Yes/No responses. With a No response, the tool advises "Do not use blockchain". I have tested this tool in at least 7 countries, when asked for advice, and all my tests have reached a rejection of Blockchain by only Step 3.

I could delve into relevant issues including immutability, transparency, handling of geospatial and energy consumption - but perhaps for another time!

7. How do you view public private partnership (PPP), especially for land registry services?

VVE: There is always scope for various levels of PPP in LA, including land registration (LR). LA and LR do not exist in a vacuum, on a global scale the land sector is perceived as highly corruption prone. Thus, PPP for LR services is highly risky, and should be applied only when there are efficient and rigid safeguards, including strong regulation, in place, – which is hard to achieve. In many transitional and developing countries such safeguards against corruption are impracticable, so very careful incremental introduction of PPP in LR services is advisable.

KCB: It's probably best I refer back to my Trilogy of articles, "Global experiences with public private partnerships for land registry services: A critical review", which Coordinates published over three consecutive months Nov 2019[10], Dec 2019[11] and Jan 2020[12]. I would encourage Coordinates readers, to especially review my concluding remarks. There are most definitely valid justifications for government to pursue PPP for land registration services especially, where the government is lacking in any or all of the following: (i) expertise and experience; (ii) investment capital; and/or (iii) good governance in the public sector. Further, PPP can be a lower risk option to pursue, with the partner maintaining and operating the infrastructure. However, the government as the purchaser and regulator, must ensure the private service provider delivers and good governance is maintained.

As I previously commented in Coordinates: *"Although the decision to contract with a private sector partner may be taken for primarily political reasons, and there may be significant negative public sentiment, nonetheless, the public interest and the rights of citizens, should always be protected by adequate safeguards, which are monitored and transparent. The ability of the government to ensure the safeguards may not be easy."*

It seems that in some jurisdictions, key government watchdogs, viz. Auditor-Generals and information privacy commissioners have raised strong concerns and are likely to be ignored if the government has a strong majority. There is a role for Auditor-Generals in reviewing risks, accountabilities, due process and business cases and to audit performance. The privacy of personal information must be protected and not exploited by the vendor.

The PPP path for geospatial information services such as a national geodetic network of Continuously Operating Reference Stations (CORS) and even for production and maintenance of fundamental geospatial data sets for the national spatial data infrastructure, may also be useful to consider. For both, the government should always retain the strong regulatory oversight roles to ensure the authoritative requirements of NSDI are retained. In the end, any decision for PPP is for the government of the day.

8. A number of tools and frameworks have been developed over the past 15 years. LGAF, IGIF, FELA are three which come to mind. What are your thoughts on the uptake and effectiveness of these?

AB: In many respects LGAF, IGIF and FELA are all different views on how to implement best practice (such as VGGT), to drive positive change and to measure impact. The utility of these frameworks very much depends on the requirements of the implementing country and the maturity of their systems. The frameworks can then be tailored to the situation on the ground. In terms of effectiveness, I defer to Keith and Vladimir.

VVE: Policy and/or technical frameworks and tools, which summarise existing empirical knowledge and wisdom in a thematic domain, are generally useful in providing standardisation, structure, guidance, and common understanding for decision makers and practitioners to improve governance and resource allocation and prioritise reform interventions. Their longevity and sustainability depend on the objective needs of countries, and on updates reflecting the dynamic changes in the thematic or technical domain. As far as LGAF, IGIF and FELA are concerned, their development and uptake seem to have been more donor-fed, than demand-led, they do not shift paradigms, nor introduce totally new concepts, mindset or cognition, but raised much needed global awareness of issues in the land and geospatial sector. From a pragmatic viewpoint, the utility of such frameworks and tools could be radically improved if they facilitated objective comparisons, monitoring and evaluation of development progress in the land and geospatial sector. From my practice in the field of geospatial information management, countries prefer unassisted, affordable, easily applied, rapid assessment tools tailored for their specific context, rather than global ones like IGIF. While FAO certainly made inputs to LGAF and IGIF, it is deliberately just an observer in FELA.

KCB: There have been quite a few, and I must say, many have been supply-driven by international agencies and their consultants with really little actual evidence of user demand. I think all provide useful checklists, but some are painfully slow and expensive to implement and actually may not bring new information to the table. In several countries, for both LGAF and IGIF I found that a rapid approach was far more expedient and effective, enabling delivery of results that were good enough. With all the frameworks, it is important to differentiate the consultant hype from reality. Unfortunately, for many countries

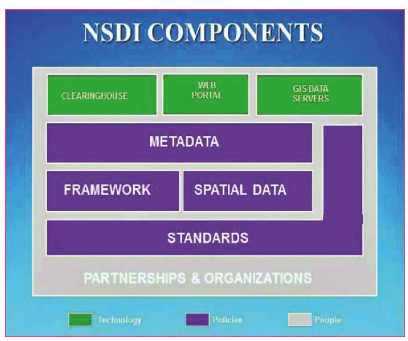
requiring donor assistance, there may be pressure or an obligation to commit to such tools as a part of the donor's consideration for investment.

Doug Nebert

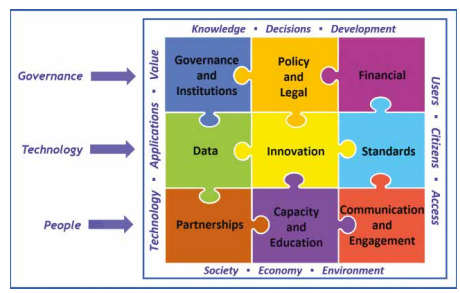
One further comment I would like to make on the frameworks specifically concerns IGIF. Undeniably, UN-GGIM has been comparatively effective in raising global, regional and national awareness of geospatial information. In my own examination of the published IGIF documentation, notably the 9 pathways of IGIF prepared by a World Bank led team of consultants working with UN-GGIM representatives, and subsequently approved by UN-GGIM, I beg to differ that it is anything new. I would add that at the World Bank, I did peer review early preparatory work for what became IGIF, so I am not coming to this as a novice. Further, I have a background of 30 years with NSDI arising from my experience in Australia in managing programs to migrate from national mapping to NSDI foundation layers. I was blessed with the opportunity to engage with Doug Nebert, of the United States Federal Geographic Data Commission (FGDC), who was the inspirational leader responsible for conceptualizing, developing and promoting NSDI in the US. It was through Doug's leadership of NSDI that realized US Presidential Executive Order 12906 - Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure, April 11, 1994, approved by then President Bill Clinton. I had the opportunity to visit FGDC around 1993, and directly engage with Doug.

One of the profound principles inculcated in NSDI was that it should be considered a soft infrastructure. In the past, national mapping and related programs, often struggled to be funded for both maintenance and further capital investment. Thus, by considering NSDI as a soft infrastructure, it was envisaged that governments would adopt similar approaches taken to the funding of hard infrastructure like roads, bridges, dams, utilities and so enable maintenance, further development and improvement. All infrastructure must be maintained otherwise it inevitably degrades and may become obsolete or non-functional. In sum, whilst one of the IGIF pathways is financial, it has really missed the raison d'etre of why NSDI is an infrastructure. When you compare the conceptual diagrams of NSDI and IGIF, there is a lot in common, but sadly IGIF claims it is more than an infrastructure, it is a framework. The framework context is very much embodied in NSDI and its sustainability and development is enshrined in the conceptualization of being a soft infrastructure.

Coordinates published a well-referenced article in May 2013: "Elements, issues and challenges in implementation of NSDI", which draws on the early FGDC thinking and other experts on the first two decades of NSDI development including the predecessor of UN-GGIM, the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP). The original elements of NSDI, including its framework and background rationale transcend the nine IGIF pathways. So, with respect, there is nothing profoundly new in IGIF other than its re-branding and packaging.[13]



NSDI Components (Source: FGDC, 2005)



IGIF – UN-GGIM Integrated Geospatial Information Framework (IGIF): 9 Strategic Pathways 2020

However, and I do reiterate, credit is due to UN-GGIM for its global, regional and national advocacy of geospatial information including NSDI through IGIF. But, as stated earlier in my response to this question, the IGIF assessment process is costly and drawn out, and more often than not, supply-driven (by the donor) rather than demand-driven (by the country). Thus, it may arguably be not fit-for-purpose. My experience in many countries has shown that a rapid approach is more cost-effective and timelier to assess a country's needs for NSDI and design its investment approaches.

The world has learned a lot from Doug Nebert's groundbreaking work, conceptualization, advocacy and awareness-raising of NSDI. Tragically, Doug, aged 51, and his 4-year-old granddaughter lost their lives in a light airplane crash in Oregon in May 2014. Doug has left a profound legacy in NSDI that continues across the globe.

9. Has the VGGT advanced land administration?

AB: The VGGT is thorough, succinct, with little ambiguity and provides a solid foundation. It firmly embeds tenure within the surrounding social governance frameworks. In my opinion it, quite rightly, identifies that tenure issues are related to the quality of governance. Further, the governance principles discuss the duality of rights and duties reflecting the complex social and spatial relationships that are framed between landowners, right holders, jurisdictions and citizens. We need more documents like this.

VVE: The VGGT is a globally negotiated and CFS[14] endorsed document setting out principles and internationally accepted standards in tenure governance, with an emphasis on conservation and protecting the interests of vulnerable and marginalized people. It was recognized as one of the ten greatest achievements

of FAO by its 70th anniversary in 2015. Its tangible positive impact on land administration is best felt in transitional and developing countries, markedly or recognition and administration of legitimate customary and indigenous tenure rights, communal and women's tenure rights, with best examples in Sierra Leone, Senegal, Uganda, Liberia, Ghana, Mali, Niger, Mauritania, Colombia, Guatemala, Mongolia, Laos, Nepal. VGGT has influenced tenure reforms also in developed economies like Serbia, Montenegro, Bosnia and Herzegovina, Albania, Kosovo, Scotland and others. The VGGT discourse in CFS is recently turning towards supplementing the land, fisheries and forests tenure governance with water tenure governance. I believe this shows the utility of VGGT for refining LAS.

KCB: I believe it has. VGGT provides a very comprehensive and useful set of principles to draw upon. In my last decade at the World Bank, the VGGT proved to be very valuable, especially in informing project design.

10. Also, what about LADM and STDM?

AB: LADM is an International Organization for Standardization (ISO) standard describing a conceptual model of social relations with land articulated through rights. LADM has been designed to be generic and applicable to all jurisdictions. As a standard, LADM dominates the domain and supports nuanced representations of Party-Right-Land relationships. STDM is a specialised subset of LADM. From a digital transformation point of view a standard like LADM is essential. However, the first edition of the LADM has a number of weaknesses notably a focus on Land Registration rather than the broader Land Administration ecosystem and poor transaction, process and legal elements. The lack of detail on transactions has led to some people questioning whether the standard is suitable to represent deeds-based registers. The revision of the LADM extends the scope of the 2012 standard towards addressing the needs of the broader Land Administration ecosystem. Given the range of agencies, parties, and activities associated with the ecosystem this is a significant change in scope. By making the standard applicable across the ecosystem rights duality issues, which are inherent in Rights, Restrictions and Responsibilities (RRRs), can be made transparent. Rights duality dictates that if a Land Register records a duty (as a restriction or responsibility) then within the Land Administration ecosystem there exists a specified third-party or authoritative agency which holds the corresponding right.

LADM is an essential part of the digital future of Land Administration. However, at present I see LADM as a guiding, rather than prescriptive, standard. That said I have modelled both deed and title registers using the underlying concepts. I expect the standard to go through further revisions as the needs of the broader ecosystem are identified.

VVE: LADM is instrumental in achieving valuable standardization in digitalizing LAS, while STDM is useful in regularization of legitimate people-to-land relations. Due to my limited experience in this field, I prefer to refrain from further comments.

KCB: LADM provides a useful framework to draw upon for the broader subject of land administration, rather than land registration. However, all too often LADM is pushed as something that must be implemented in its entirety for land registration. Many of the interests of LADM are highly relevant to the broader and administration context and are interests that should not be and do not need to be registered. Having them accessible, online, rather than registered as part of the tenure Rights, Restrictions and Responsibilities (RRR) is important. LADM is long-overdue for revision. It was endorsed by ISO back in 2012. Full credit to those who developed LADM and have promoted it. As for STDM, it's really a subversion of LADM and has been usefully promoted especially by UN-Habitat.

11. Cadastre 2014[15] was published in 1998 by FIG. Is it still relevant? Any other thoughts?

AB: Cadastre 2014 is a milestone publication. It has been the catalyst that frames many of the significant developments and thinking over the last 25 years. Fit-for-purpose can be seen in the comments about aspiring to 'cadastral perfection'. LADM can be seen in the way concepts, rules and relationships are described and the modelling requirements of statement 4. Communities need a vision, a "north star" which will guide developmental trajectory. Cadastre 2014 provided this. Clearly some 'course correction' needs to be applied to reflect current technical, political and social contexts. However, the 6 statements are still broadly relevant and represent challenges that the community still need to properly address.

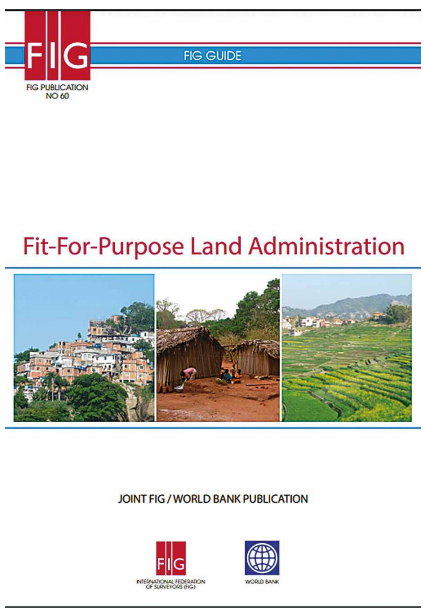
VVE: This flagship FIG publication is a major factor to motivate and inspire reforms and improvement of LAS worldwide – very notably in my own region. I personally translated it into Bulgarian, built awareness and popularised it in the Balkans, in transition economies of Central and Eastern Europe and Central Asia. It is still quite relevant in many transitional and developing countries where the digital divide is apparent, and whose LA and geospatial system reforms are lagging behind. Even though in my view the paradigm shifted from (multi-purpose) cadastre to spatial data infrastructures, the essence of 'Cadastre 2014' messages is unchanged and helps in promoting the concept of continuous improvements and making LA reforms business as usual.

KCB: At the FIG 2018 Congress in Istanbul, I was the first speaker in the final plenary session, chaired by one of the authors of Cadastre 2014, Dr.

Daniel Steudler. Daniel is now FIG Vice-President. As it was the 20th anniversary of the publication, I took the opportunity in my opening remarks to congratulate Daniel and to commend Cadastre 2014 as a wonderful "think-piece' and arguably the most praised and criticized land administration publication.[16] Cadastre 2014 remains relevant, with due regard given to its context and purpose.

12. FIG published Fit-For-Purpose Land Administration, Publication 60, in conjunction with the World Bank in 2014. Has it been the game changer that is sometimes espoused?

AB: Fit-For-Purpose Land Administration (Publication 60: FFPLA)[17] is an important publication. It is about the pragmatics of change. While the original publication feels like it is geared to developing countries, the core principles can be applied to any jurisdiction at any stage of maturity. The thinking behind FFPLA is fundamental to any digital transformation programme and I've definitely found it useful in my work. Every agency should have a mantra stating the "accuracy relates to the purpose rather than technical standards" and build in "opportunities for updating, upgrading and improving" processes and data. The phrase "fit-for-purpose" has become a useful short-hand during discussions.



Enemark, S., et al, (2014), Fit-for-Purpose Land Administration, FIG Publication 60 https://fig.net/resources/publications/figpub/pub60/figpub60.asp

It would be useful to distil FFPLA and some of the other core thinking into something similar to the *agile manifesto*[18] for software development. At just 68 words the agile manifesto is snappy, accessible, and has had enormous impact in the software development domain. A succinct summary of the high-level guiding principles of Land Administration could have similar impact.

VVE: FFP LA is another FIG flagship publication – a must-have reference bible – for development professionals in the LA and geospatial domain. It encourages positive disruption and reform for many LAS in transitional and developing countries, reminding decision makers and practitioners of good old fit-for-purpose principles of surveying and mapping.

KCB: That's a good question! Personally, I don't think Fit-For-Purpose Land Administration (Publication 60)[19] has been a game changer, but it has been an excellent think-piece to inform, consider and provoke. From that perspective, I can reflect on my own contributions as a co-author, and I consider it one of FIG's most useful publications. My sincere congratulations and respects to lead author Stig Enemark who has so effectively promoted FFPLA over the years since the launch in 2014. In short, FFPLA provides a very useful reference to support the design of a land administration system and to support incremental improvement of existing systems. There is no blueprint or template to be followed as every jurisdiction is unique, but you can learn from the experiences from elsewhere.

13. Any thoughts on the continuum of land rights?

AB: The Continuum of Land Rights attempts to represent how rights of tenure are given legitimacy (security) through different social frameworks. I think it does this poorly by simply stating that different tenure types have different tenure security attributes. This ignores the social legitimacy given to tenure through formal and informal governance frameworks. Something that is well described in the VGGT.

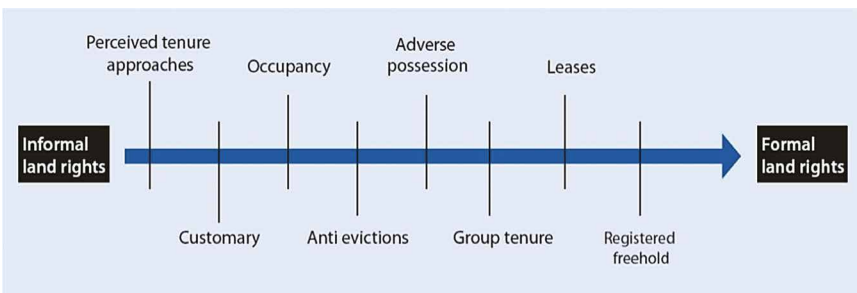
In many jurisdictions social legitimacy is provided through a legal framework. However, social legitimacy can be provided through community or other social frameworks. It is possible to have high tenure security within a community governed system as long as there is social recognition of both the right and the claim of the right holder. The issue is how resilient the governance frameworks are to disruption.

The Continuum of Land Rights does not represent this nuance and results in something which could be misleading or unhelpful. The diagram seems to view tenure through a 'western lens' that oversimplifies social relations, transhumance and overlapping rights scenarios and undervalues the role of governance. The fact that UN-HABITAT and Global Land Tool Network (GLTN) produced an 88-page document to support scenario building using the continuum of land rights[20] demonstrates the complexity of the topic.

VVE: The phrase enjoys popularity, even though a 'continuum' of land rights is a nonsense. A discreet plethora, or range of rights exists within the bundle of land rights, and they neither can be clearly arranged as lesser or superior, nor are a continuum. Anyway, incremental or sizeable leaps to better tenure security can be practically achieved by development interventions, depending on the specific legal framework of a jurisdiction, windows of opportunity, local circumstances and other complex factors. I disagree with the term but agree with the idea of phased improvements of tenure rights security. The globally negotiated and agreed VGGT have no mention of a 'continuum' of land rights, perhaps the term 'continuum'

was deemed misleading. It was coined recently, so if one strives for perfection and tries to use precise terminology, the 'continuum of land rights' should be replaced with a more precise phrase. Sticking to a wrong term deflects the message that LA and geospatial community of practice is trying to send to policy and decision makers and donors.

KCB: Indeed, I have thoughts – long held thoughts – on which I have spoken out over the past 15 years. I profoundly disagree with the concept of the Continuum of Land Rights or the Continuum of Tenure Rights, as it is sometimes called.[21] By definition a continuum is a continuous sequence in which adjacent elements are not perceptibly different from each other, although the extremes are quite distinct. Now, that's a dictionary definition. Tenure is not a continuum – it is not a continuous sequence. There is a broad spectrum of tenure types. I would argue that what is wrong with the Continuum is the inference that it's a progression from left to right from informal tenure through a range of different types to leases and registered freehold. The concept poorly reflects customary and community tenures including nomadic rights. I also reject that the Continuum of Land Rights is a metaphor. A metaphor is a thing regarded as representative or symbolic of something else, especially something abstract. The Continuum is misleading and under- represents the full spectrum of different tenure types and would wrongly imply that registered freehold is the highest form of tenure type.



14. How beneficial is the role of multilateral agencies like the World Bank in Land Administration? Share a success story example.

VVE: Frankly speaking, I may be biased, since I have been collaborating with multilateral agencies, including the World Bank, since the 1990s, and I currently work for the largest UN technical agency. It is hard to imagine what would have been the status of LA in my own region without development support from multilateral agencies, or without the international knowledge exchange that they stimulate. Land surveyors are among the first professionals who recognized the value and importance of international knowledge exchange by establishing FIG, the *Fédération Internationale des Géomètres*, in 1878. For me, the development partners support for reforms in the LA and geospatial domain is *sine qua non*. One indicator for perceived benefits of WB and other development partners support in LA and geospatial reforms is the fact that several well-developed economies – even among the G20 – keep requesting WB and other development partners assistance. The key effort should be to further improve the efficiency and effectiveness of such international support. I already mentioned Kyrgyzstan as an example, where the WB supported LA projects of the government, which were considered to have improved people's lives. The Kyrgyz LAS achievements ranged from four hours on the average to register an apartment sale with a hypothec, to the fact that short term loans using land as collateral became so efficient and accessible, that the total annual amount of LAS-registered loans to citizens (supporting local economic development) exceeded the foreign direct investments.

KCB: Overall, I would say it's been positive. Back in the October 2011 issue of Coordinates, I had an article published, "Experiences from World Bank Development Support for Land Reform". It is relevant to the question being discussed here.[22] There have been successes but there have also been failures. Success requires clarity, ownership and sustainability. Land administration projects require well-defined objectives, activities, and should focus on what is truly achievable within the investment life of the project. Such investment should identify the issues and challenges and build on successes. To be effective, the project should have well-defined targets and baselines within a responsible project results framework. However, things can and do change, so flexibility is essential which means project revision – or restructuring – may be necessary. I am not aware of a single World Bank supported land administration project that did not require restructuring within the first two years of a typical project period of five years.

I would say the three Land Titling projects in Thailand, supported by the World Bank and Australian Technical assistance, over the 18-year period 1984- 2002, were very successful. The projects implemented the first three phases of a proposed 20-year land titling program. Subsequently, the government continued to implement the land titling program, using its own funding. I would like to also report that I consider several other successful land administration projects including Laos Second Land Titling Project, Philippines Second Land Administration and Management Project, Indonesian Reconstruction of Aceh Land Administration System Project, Vietnam Land Administration Project, Uzbekistan Modernization of Real Property Registration and Cadastre Project and the Support to the Land Administration and Geospatial Modernization Project

and Türkiye Land Registry and Cadastre Modernization Project. The World Bank project website has all the project details, data and documents for free download.

15. We frequently see in publications and reports from development agencies, including the World Bank, that 70% of the world's land parcels are not registered. That suggests a huge challenge still remains despite more than three decades of development assistance by the World Bank, et al. What are your thoughts?

VVE: This kind of fake statistic, with obscure underlying assumptions, is used by well-intended activists mostly for populistic advocacy. For the sake of argument, is a percentage of non-registered land parcels a good proxy of land tenure insecurity and land inequality? Unintentionally, FAO may have contributed to generating and disseminating such confusing numbers on the global land tenure status. The unflattering truth is that we very well know there are widespread land tenure insecurity and inequality in the access to land and other natural resources, – adversely affecting livelihoods and human rights of the marginalised and vulnerable ones, constantly fomenting conflicts and hampering socio-economic development and environmental resilience, – but reliable statistical data about the global dimensions of land inequality and tenure insecurity are still missing. The land-related indicators were hastily patched to the SDG in the last minute, with insufficient participation and inclusion of key stakeholders – for example, the FAO Land Tenure Unit supporting the VGGT was practically not part of the consultations. This highlights a long standing negligence and absence of land access and tenure insecurity issues from the global sustainable development agenda and priorities. SDG indicators 1.4.2, 5.a.1 and 5.a.2 are apparently insufficient to get the full global picture of access to land and tenure insecurity. Moreover, they are not properly reported by the UN member countries so far. The magnitude of the challenge has to be well estimated in order to enable managing the problem and monitoring the progress towards its mitigation. Land tenure statistics are close to my heart: one of my first FAO assignments, even before I joined FAO, focused on land tenure statistical data in Central and Eastern Europe. LAS should be among the key providers of land tenure data for statistics, but there are many tenure data types that should be collected by other land sector stakeholders. In fact, many LAS lack the capacity to provide adequate land tenure data for national statistics. Anthony Beck emphasized in a discussion that this should be addressed. Modern LAS should be able to provide flexible statistics to support exploratory analysis, policy and decision making. If they cannot, then the implication is that they have been designed in an inflexible way. My opinion is that the global importance of land tenure statistics is commonly underestimated, and such statistics are not yet adequately mainstreamed in the UN Statistics Division. On a positive note, FAO supports the initiative to establish a global land observatory and periodically publish a global land report, which is a step in the right direction to fill the current gap. Hopefully this initiative will be soon backed by multiple international, government and civil society stakeholders in the land sector to make it a success.

KCB: Firstly, no one knows how many land parcels there are in the world, let alone being able to advise a percentage of an unknown figure. That should just be plain common sense. The background to what has become known as the Zombie Myth – 70 percent of the world's land parcels are not registered or alternatively only 30 percent of the world's land parcels are registered – is a profoundly false equivalence from an exercise by eminent land expert Willi Zimmermann who was tasked by FAO, around 2010, to estimate the percentage of the world's population which lacked secure tenure. I understood this was a consideration for development of the VGGT. Importantly, Willi Zimmermann did not report on the percentage of land parcels. I discussed this with Willi some years ago due to the growth of the Zombie Myth and its many variations. Willi, with inputs of 10 experts did some very rough guestimates and considered that around 70 percent of the world's population lacked tenure security. So, it's completely without basis to claim that 70 percent of the world's land parcels are not registered or not titled. Regretfully, this Zombie Myth continues to be reproduced, or a variant of it, in many publications, reports and presentations by leading development agencies, including the multilaterals. I understand that the UN Statistics Division, the parent of UN-GGIM, has access to the periodic population housing censuses and agricultural censuses of some 150 countries of the world's reported 195 countries. Reliable figures on tenure security could be obtained by using the census data, and periodically revised from new census data, to monitor progress.

16. Any comments on the World Bank Doing Business (DB) ratings for Registration of Property (RP)? It was last published in 2020.

VVE: I am familiar with the RP section of the DB and have seen it used to advocate for tenure reforms, but I have my doubts on the representativeness and objectivity of its ratings and see it as a populistic hype. First, RP methodology did not measure LAS efficiency for the mass land transactions – sale of a residential property, – but used instead the sale of a hypothetical warehouse – quite a rare transaction, – thus considerably reducing its representativeness. Second, it was so populistically advertised without revealing the underlying assumptions, that it created a hype and unhealthy competition between governments to score well, – since a good rating meant better chances for foreign investments in the economy. In at least

one country, government counterparts advised about special missions of top officials to Washington D.C., negotiating amendments of their RP rating, – which is a blemish on RP and DB presumed impartiality. Therefore, I was not surprised when the WB group announced DB termination.

KCB: Just a few comments. Firstly, I do recall Coordinates carrying a brief news update on DB back in September 2020 concerning "data irregularities".[23] Of course, the irregularities were not isolated to any single indicator. One year later, following an independent investigation by the US law firm Willmer Hale, the World Bank advised that it was discontinuing DB and made public the Willmer Hale report[24,25]. So, the last report prepared was June 2020. To quote from the World Bank media release:

"After data irregularities on Doing Business 2018 and 2020 were reported internally in June 2020, World Bank management paused the next Doing Business report and initiated a series of reviews and audits of the report and its methodology. In addition, because the internal reports raised ethical matters, including the conduct of former Board officials as well as current and/or former Bank staff, management reported the allegations to the Bank's appropriate internal accountability mechanisms.

After reviewing all the information available to date on Doing Business, including the findings of past reviews, audits, and the report the Bank released today on behalf of the Board of Executive Directors, World Bank Group management has taken the decision to discontinue the Doing Business report."

Subsequently, the World Bank has announced it will be implementing Business Ready (B-READY), to replace DB. B-READY will assess the business and investment environment, or business enabling environment (BEE) worldwide annually. Whilst I am not aware of the exact status of B-READY, I understand it's past the Concept Note stage and the first publication will be Spring 2024. B-READY will provide a quantitative assessment of the business environment for private sector development. The assessment will cover ten assessment topics following the typical life cycle of a firm from opening, operating (or expanding), and closing (or reorganizing) a business. It is my understanding that Registering Property will not be included in B-READY - which is appropriate as it is intended to assess the business and investment environment rather than the bulk of land registrants which are ordinary owners.

To return to the topic of DB Registering Property, many did not realize it was a hypothetical assessment and it did not cover residential or agricultural property. Rather it was a hypothetical owner-occupied warehouse or factory of particular characteristics of size, location, mortgage-free and so forth to address private sector use of property for business. To be frank, warehouses and factories do not often get sold. Most are subject to lease agreements. Thus, such transactions would be among the least common in any land registry and most definitely not a valid proxy for general registration of property. Thus, to reiterate, it was about the doing business aspects of property – private sector business – and not about general rights over residential and agricultural lands for ordinary citizens. Further, to see countries with poor and incomplete cadastral systems often achieving high ratings for Registration of Property was just extraordinary. Over the period from 2010-17 I used to annually prepare a spreadsheet tabling DB RP against Transparency International's Corruption Perception Index[26] and the International Property Rights Index (IPRI)[27]. Many, but not all, of the highly ranked DB RP countries had poor CPI rankings and did not do well under IPRI. One example that stood out in 2017, my last effort, was Russia, which ranked very high on DB RP at 12th out of 190 countries covered under DB. IPRI had ranked Russia 111th out of its 125 ranked countries and TI CPI ranked Russia 133rd out of its 180 ranked countries.

17. The United Nations Sustainable Development Goals (SDGs) are 17 goals with 169 targets that all 191 UN Member States have agreed to try to achieve by the year 2030. We are now at the mid-point of the period of the SDGs – 2016-2030. The SDGs contain land-related targets and indicators under SDGs 1, 2, 5, 11 and 15. What are your thoughts?

VVE: My organization is aware that despite the need for responsible governance of land tenure for the achievement of nearly every SDG, the world's attention to this matter was sadly dropped off of the global priority list. This undermines efforts to foster sustainable agrifood systems, as well as to fortify the protection of human rights. We are not at all on track to achieve the SDG targets by 2030 and the world is currently facing unprecedented challenges: the COVID-19 pandemic, food insecurity, climate change, land degradation, biodiversity loss and ecosystem disruption, water scarcity, forced migration and conflicts. From narrow LA and geospatial perspective, to overcome these challenges, it is crucial that governments and their development partners take stock of lessons learned and double down on efforts in strengthening the responsible governance of tenure, in line with VGGT.

KCB: According to the Sustainable Development Goals Report 2023: Special Edition, in terms of all targets, only 15 percent are on target, 48 percent are moderately or severely off track and 37 percent are at stagnation or regression.[28] Let's focus on tenurial rights as reported under SDG 5. The Special Edition advises that agricultural land ownership and legal protection of women's land rights remain low. Specifically:

- When it comes to legal frameworks, close to 60 percent of the 71 reporting countries have no or low levels of protection for women's land rights.
- In 46 of the reported countries, less than 50 percent of women and men

have land ownership or secure rights.
- the share of men with ownership is at least twice that of women in the reported 46 countries.

On the positive side, 51 percent of the 41 countries with laws recognizing customary law or customary land tenure explicitly protect women's land rights. However, the actual reporting of such a small number of countries out of 191 UN member states is surely a serious issue.

It is the midpoint of the SDGs. UN Secretary-General Guterres has advised:

"Halfway to the deadline for the 2030 Agenda, the SDG Progress Report; Special Edition shows we are leaving more than half the world behind. Progress on more than 50 percent of targets of the SDGs is weak and insufficient; on 30 percent, it has stalled or gone into reverse. These include key targets on poverty, hunger and climate. Unless we act now, the 2030 Agenda could become an epitaph for a world that might have been."

It seems that the UN either rejected or ignored the advice of former UN Special Rapporteur Philip Alston, in his final report, to restructure (revitalize) the SDGs.[29] Alston was also highly critical of the World Bank's measures of extreme poverty. Clearly, the failings of the first set of goals, the Millenium Development Goals, were not effectively addressed. In previous SDG Annual Reports, dating back to at least 2020, UN Statistics Division, and its parent the UN Department of Economic and Social Affairs (DESA) advocated the acquisition of more data, including geospatial information, to address the SDGs, rather than restructuring. That has clearly been proven wrong and sadly Alston's advice was either ignored or rejected. Clearly, there are missed opportunities. It may be too late now to fix things before 2030. Any fixing is likely to just revise targets and improve data collection – and that could be interpreted as restructuring to make things look not so bad. Perhaps attention needs to be paid to lessons learned and to prepare for the next set of 15-year goals. There is no doubt that geospatial information is important for monitoring of targets and UN-GGIM's advocacy of such is appropriate.

18. One question on disasters striking at so frequent intervals of 'never imagined' intensity. What is it all indicating towards and what does it mean for land administration?

VVE: Regardless of whether the increasing frequency of news on natural disasters and their intensity is a result of climate change, or of improved global information and communications, the takeaway for LA and geospatial systems is that they should plan how to improve their own resilience to disasters, and how to help improve the national and community resilience in their countries by improving their services. I believe that public investments in LA and geospatial systems and PPP expansion in this domain should be prioritised in order to achieve better resilience in the long run.

KCB: It highlights a number of critical issues, especially concerning resilience. Firstly, land registry records must be secure and should be digital and frequently archived and stored separately. My experience in Aceh after the tsunami showed how vulnerable paper records were to destruction. I have also seen it with other disasters including fire. Secondly, planning approval is an important subject under land administration. Residential occupation of lands subject to flooding, storm and tidal surge should also be projected, unless it is mandated to build above perceived flood levels. That is, an additional amount of height above the Base Flood Elevation should be used as a factor of safety (e.g., 0.6-1.0 m above the Base Flood) in determining the level at which a structure's lowest floor must be elevated or floodproofed to be in accordance with jurisdictional planning floodplain management regulations. This is called Freeboard. A further issue is not occupying land below the Mean High-Water Mark (MHWM) and, in some circumstances, pulling well back from MHWM. I recall that working in Leyte following super- typhoon Yolanda and advising on a no build zone for coastal properties, which was subsequently fixed at 40 meters setback from MHWB for residential purposes. Business purposes land use setback was not changed. I recall advising a higher setback from MHWM, but ultimately, it was a government decision.

In sum, land administration systems must be resilient and sustainable, with all information being secure and maintained. People's rights and utilization of rights must be protected. Access to authoritative data, including elevation and buildings, underpinned by a reliable cadastral base, enables simulation for disaster planning and mitigation. I see enormous opportunities for Digital Twin applications in supporting resilience.

19. Any final brief thoughts?

AB: Firstly, Digital Twins essentially establish two parallel systems: the abstraction (or the model) and the reality. Inevitably the model will never fully reflect reality. Individuals and organisation become heavily invested in the modelling. Frameworks and metrics are also developed to support implementation and to benchmark, measure and evaluate change. Careers and reputations can be built on how well such models are adopted.

Where the model is demonstrably weak or inappropriate for a scenario then there is also a risk that vested interests will defend the abstractions. This can create a tension between the model, reality and the problem in hand, which can become a significant distraction. In this world of digital twins, LADM, LGAF, IGIF, FELA, FFPLA, and SDGs we should remember the words of statistician George Box: *"All models are wrong, but some are useful"*[30]. The point being that the utility

of a model should be judged on how useful it is; when a model stops being useful then the model is not fit-for-purpose.

Finally, I would like to see horizon scanning documents identify high level implementation roadmaps. Horizon scanning is useful for exploring the future and identifying potential threats, opportunities and developments that may affect current policies and practices. I like it. However, horizon scanning can very easily create unrealistic expectations (a little like the Gartner hype cycle[31]). I feel this is happening in respect of the application of technology to Land Administration.

For example, UNECE Principle 20 (UNECE, 2021, p. 13)[32] states that *"The land administration system offers real-time registration of transactions, largely subject to automatic digital checks only"*. This is highly aspirational. It requires the development of foundational prerequisites including an LADM style 'data' architecture, automated validation of cadastral surveys, a party indexing system which can be dynamically accessed to determine identity, professional accreditation and power-of-attorney details. This doesn't even consider the range of associated legal reforms a jurisdiction would need to put in place to make such a proposal viable.

Expectations shape the art-of-the-possible and influence future policy. It is important that architects of change can develop policy that can be implemented and recognise what companion steps are needed to deliver the intended changes.

VVE: I am very grateful to Coordinates for inviting me to participate in this virtual interview. I hope that this interview will instigate further useful discussion.

KCB: For all those engaged in international development assistance, including research and analytical works, and especially in the areas of land administration and geospatial, please keep an open mind. Be prepared to challenge the apparent consensus, sometimes dominated by loud voices and hype, which really grew during the pandemic. Good ideas and approaches can only emerge from constructively challenging and questioning. As General George Patton (1944) is often cited:

"If everyone is thinking alike, somebody isn't thinking."

I hope this interview provokes discussion and debate. Many thanks to Coordinates for inviting me to participate and share some of my thoughts alongside my respected colleagues Vladimir and Anthony.

End notes

[1] https://www.fao.org/tenure/gt4t/geotech4tenure/en/
[2] International Fund for Agricultural Development
[3] Cf. Bill Gates: "The first rule of any technology used in a business is that automation applied to an efficient operation will magnify the efficiency. The second is that automation applied to an inefficient operation will magnify the inefficiency."
[4] https://oig.usaid.gov/sites/default/files/2018-06/5-306-09-004-p.pdf
[5] https://www.sigar.mil/pdf/ audits/SIGAR-17-27-AR.pdf
[6] Cf. Hull S. et al. An Overview of Frontier Technologies for Land Tenure: How to Avoid the Hype and Focus on What Matters, https://www.mdpi.com/2073-445X/11/11/1939
[7] https://www.gartner.com/en/research/methodologies/gartner-hype-cycle
[8] https://nvlpubs.nist.gov/nistpubs/ir/2018/NIST.IR.8202.pdf
[9] https://www3.weforum.org/docs/48423_Whether_Blockchain_WP.pdf
[10] https://mycoordinates.org/global- experiences-with-public-private- partnerships-for-land-registry- services-a-critical-review/
[11] https://mycoordinates.org/global-experiences-with-public-private-partnerships-for-land-registry-services-a-critical-review-2/
[12] https://mycoordinates.org/global-experiences-with-public-private-partnerships-for-land-registry-services-a-critical-review-3/
[13] https://mycoordinates.org/elements-issues-and-challenges-in-implementation-of-nsdi
[14] UN Committee on World Food Security
[15] Kaufmann J. and Steudler D., Cadastre 2014: A Vision for a Future Cadastral System, FIG 1998.
[16] https://www.youtube.com/watch?v=Tyl7VA3SlzI
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[20] https://unhabitat.org/sites/default/ files/download-manager-files/ Framework%20for%20Evaluating%20 Continuum%20of%20Land%20 Rights%20Scenarios_English_2016.pdf 21 https://unhabitat.org/sites/default/files/ download-manager-files/Secure%20 Land%20Rights%20for%20All.pdf
[22] https://mycoordinates.org/experiences- from-world-bank-development- support-for-land-reform/
[23] https://mycoordinates.org/ doing-business-world-bank-issues- data-irregularities-statement/
[24] https://www.worldbank.org/en/news/statement/2021/09/16/world-bank-group-to-discontinue-doing-business-report
[25] https://thedocs.worldbank.org/en/ doc/ 84a922cc9273b7b120d49ad3b9e9d3f9 - 0090012021/original/DB-Investigation-Findings-and-Report-to-the-Board-of-Executive-Directors-September-15-2021.pdf
[26] https://www.transparency.org/en/cpi/2022
[27] https://www.internationalpropertyrightsindex.org/about
[28] https://unstats.un.org/sdgs/report/2023/
[29] https://www.ohchr.org/en/documents/thematic-reports/ahrc4440- parlous-state-poverty-eradication- report-special-rapporteur
[30] https://en.wikipedia.org/wiki/All_models_are_wrong
[31] https://www.gartner.co.uk/en/methodologies/gartner-hype-cycle
[32] https://unece.org/sites/default/files/2021-12/Scenario%20Study_E_0.pdf

Understanding the RINEX format for GNSS data transfer and storage

This paper provides a brief history of the RINEX format, presents examples of recent RINEX format versions and discusses the editing of RINEX observation files.

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The Receiver Independent Exchange (RINEX) format is the international standard for the storage and exchange of Global Navigation Satellite System (GNSS) data. It not only enables interoperability between receiver brands and processing software packages but also the generation of many valuable products and services to the GNSS user community by the International GNSS Service (IGS). The RINEX format allows efficient and unambiguous archiving of GNSS data and associated metadata in one place (in a human-readable form), while also facilitating the easy transfer and distribution of such data, independent of the equipment used to collect it and the engine employed for data processing.

RINEX files are universally used by international organisations, academia, national organisations, all levels of government and private industry. Online processing services, such as Geoscience Australia's free online Global Positioning System (GPS) processing service, AUSPOS (GA, 2023), and the CSRS-PPP online Precise Point Positioning (PPP) service provided by Natural Resources Canada (NRCan, 2023), require the user to submit data in RINEX format. Consequently, it is important that users understand the contents and format of these files.

The Geocentric Datum of Australia 2020 (GDA2020) is Australia's national datum and based on a single, nationwide least squares network adjustment that rigorously propagates uncertainty (Harrison et al., 2023). DCS Spatial Services, a unit of the NSW Department of Customer Service (DCS), is responsible for the establishment, maintenance and improvement of the survey control network in New South Wales (NSW), which comprises more than 250,000 survey marks on public record made available to users via the Survey Control Information Management System (SCIMS).

DCS Spatial Services uses RINEX files in providing services to its customers and the broader surveying profession as well as interacting with federal counterparts to support national initiatives. Focussing on GNSS observation files, this paper provides a brief history of the RINEX format, outlines examples of recent RINEX format versions and discusses the editing of RINEX observation files.

Brief history of RINEX

All manufacturers store raw GNSS (and most other survey instrument) data in proprietary, binary (non-human readable) data formats that are designed to be compact, optimise specific observations, enhance performance with their own algorithms and software modules (or complete software suites) and that lock users into their brand. As such, swapping raw survey data between brands was never intended. That was until RINEX was invented.

The RINEX format was initially developed in the late 1980s by the

Astronomical Institute of the University of Bern, Switzerland, to facilitate the easy exchange of GPS data to be collected during the first large European GPS campaign, EUREF89, which involved more than 60 GPS receivers of four different manufacturers (Gurtner et al., 1989). It defined three different file types: observation data file, navigation message file and meteorological data file. The reader is encouraged to appreciate the complexity and delicacy of negotiations and confidence that was entrusted to this organisation to initially gain access, and then continued access over the decades, to the proprietary Intellectual Property (IP) of each of the major manufacturers and the very idea of championing interoperability.

Each RINEX file consisted of a header section containing metadata related to the station occupied and the equipment used, followed by a main body with the actual data. The files were designed to have a maximum line length of 80 characters, written in American Standard Code for Information Interchange (ASCII) to enable humans to read (and edit) the data and guarantee an easy exchange between different computer systems. The cost of being human-readable is that RINEX files are always larger in size than the raw format files. The observed GPS data included the carrier-phase measurement on one or two frequencies, the pseudo-range (code) measurement, the Doppler measurement, the signal strength and the observation time.

Through the RINEX format, it was possible to combine data observed by a multitude of receiver brands and models in order to be processed together. Over many years, and under the umbrella of the IGS, the RINEX format has since been modified, expanded and improved to allow multi-GNSS data to be handled, thus becoming the international standard used for the transfer, archival and distribution of GNSS data by the IGS and countless other users in the GNSS community worldwide (IGS, 2023a). For example, this has resulted in the computation of the ever-improving International Terrestrial Reference Frame (ITRF – see Altamimi et al., 2023).

Based on the collation and processing of globally collected GNSS data, the IGS provides a wide range of valuable products to the GNSS user community, including precise satellite orbits and clocks, terrestrial reference frame products (e.g. station positions and earth rotation parameters) and global ionospheric maps (IGS, 2023b). Without RINEX, this collaboration and its benefits, along with open, regional Continuously Operating Reference Station (CORS) networks such as CORSnet-NSW (Janssen et al., 2016; DCS Spatial Services, 2023), would have been impossible. The alternative would have been for each manufacturer to build and operate their own closed proprietary system. Understandably, the costs would have been prohibitive.

In the mid-1990s, the success of the RINEX format spawned a spin-off: the Solution Independent Exchange (SINEX) format, which is used by the geodetic community to store and transfer solutions of various parameters derived in various types of analysis (e.g. AUSPOS solutions containing more detailed information for advanced users). This was followed by a family of other RINEX-like file formats (IGS, 2023a) that are mainly used by the IGS, including exchange formats for satellite and receiver clock offsets determined by processing data of a GNSS network, for Space-Based Augmentation System (SBAS) broadcast data files, for ionosphere models determined by processing data of a GNSS network (IONEX), and for phase centre variations of geodetic GNSS antennas (ANTEX).

To date, the following four versions of RINEX have been developed and published (Gini, 2023):

- The original RINEX version 1 was presented at and accepted by the 5th International Geodetic Symposium on Satellite Positioning in Las Cruces, New Mexico, in 1989.
- RINEX version 2 was presented at and accepted by the 2nd International Symposium of Precise Positioning with the Global Positioning System in Ottawa, Canada, in 1990. It mainly added the possibility to include tracking data from different satellite systems (i.e. GLONASS, SBAS). Over time, it was modified via several sub-versions, culminating in version 2.11.
- RINEX version 3 was developed in the early 2000s and initially released in 2007 to support multi-GNSS and clearly identify the tracking modes of each of the observations by introducing 3-character observation codes for all GNSS constellations. Over time, it was modified via several sub-versions, culminating in version 3.05.
- RINEX version 4 was released in 2021 as a necessary step to support the modern multi-GNSS navigation messages by introducing and defining navigation 'data records' to hold both individual satellite navigation messages, constellation-wide parameters and global parameters as transmitted by the different GNSS constellations. It has since been updated to version 4.01.

Examples of recent RINEX versions

While it is recognised that the RINEX format encompasses observation data, navigation data and meteorological data, along with extensions such as satellite and receiver clock data and SBAS broadcast data files, this paper focuses on RINEX observation files as these are the most important for surveyors in practice (and the most likely to be edited). Apart from using the broadcast ephemeris data collected by their own receiver, surveyors can easily obtain precise orbit files from various sources if required (e.g. via IGS, 2023b), and the other files are generally not used in common surveying applications.

RINEX 2.11

Following several revisions for improvement and clarification, RINEX 2.11 (Gurtner and Estey, 2012) is the last official RINEX version 2 format. Its major difference compared to the original RINEX version 1 format is that

it caters for tracking data from different satellite systems in addition to GPS. This format is currently being used by DCS Spatial Services for archiving AUSPOS datasets for inclusion into the GDA2020 state adjustment, partly because AUSPOS remains GPS-only at present (Janssen and McElroy, 2022).

The RINEX file name must not contain any spaces, parentheses or symbols. It is beneficial to use the international RINEX 2.11 file naming convention XXXXDDDS.YYO consisting of 8 characters followed by a 3-character extension, where XXXX is a 4-character site name, DDD is the day of year (i.e. 001 to 365, or 366 during a leap year), S is the session identifier (i.e. 0 to 9, or A to X indicating the first observation epoch's hour of the day with A = 0 hours and X = 23 hours), YY is the 2-digit year (i.e. 23 for the year 2023) and the letter O indicates that this is an observation file.

RINEX file name extensions are sometimes further refined to indicate the type of compression that may be used to reduce the ASCII file size. Hatanaka (2008) developed a compression scheme and related software tools that take advantage of the structure of the RINEX observation data by forming higher-order differences in time between observations of the same type and satellite (indicated by the extension .YYd). This compressed ASCII file is then often compressed again using standard compression programs, e.g. yielding a UNIX-compressed (.YYd.Z) or gzip-compressed (.YYd.gz) Hatanaka RINEX file.

The RINEX file consists of a header section (including mandatory and optional records) followed by a data section and ends with a blank line, each row being a maximum of 80 characters long. A single RINEX file should only include a single occupation on a single mark. The header section contains information for the entire file, including mandatory header labels in columns 61-80 for each line in the header, which must appear exactly as stipulated. The header information must also appear in the correct columns to be valid, e.g. antenna information and antenna height. This is of particular importance when the RINEX header is edited.

Figure 1 shows an example of a typical RINEX 2.11 header. It includes the following information:

- Line 1: RINEX version, specifying an observation file with mixed GNSS data (e.g. as opposed to GPS-only).
- Line 2: Program used to generate the RINEX file, who ran it (here blank) and when it was run.
- Line 3-4: Comments (can be placed anywhere between the first and last line in the header).
- Line 5: Marker name, in this case the 4-character ID issued to NSW by Geoscience Australia.
- Line 6: Marker number, here the SCIMS number.
- Line 7: Observer and agency, here NSW (i.e. DCS Spatial Services).
- Line 8: Receiver serial number, receiver type and firmware version.
- Line 9: Antenna serial number (for integrated antennas the same as the receiver serial number) and antenna type (using the IGS naming convention).
- Line 10: Approximate site position in WGS84 Cartesian coordinates (X, Y, Z).
- Line 11: Antenna height (measured vertically between ground mark and Antenna Reference Point, ARP) and any horizontal offset from the mark (i.e. small horizontal eccentricities of the ARP to the marker, which are typically zero for all but some scientific applications).
- Line 12: Wavelength factor for the L1 and L2 frequency, in this case indicating full cycle ambiguities for both frequencies.
- Line 13: Number and types of observations, here L1, L2, C1, P2, S1, S2 – i.e. carrier phase measurements, code measurements and signal strengths on the L1 and L2 frequency, respectively.
- Line 14: Sampling interval, in this case 30 seconds.
- Line 15-21: Comments, here including the name of the raw binary data file.
- Line 22: Time of first observation epoch, here 00:37:30 hours (GPS time) on 1 June 2021.
- Line 23: Number of leap seconds between GPS time and UTC, in this case 18. GPS time started at 00:00:00 UTC (midnight) on 6 January 1980 (i.e. Sunday morning). Since then, several leap seconds have been introduced to UTC (but not GPS time), currently resulting in GPS time being 18 seconds ahead of UTC.
- Line 24: End of RINEX header indicator.

Figure 2 shows a typical RINEX 2.11 observation data block. It contains the following information:

- Line 25-26: Date and time of the observation epoch (receiver time of the received signals) in the format year, month, day, hours, minutes, seconds (here 00:37:30 hours on 1 June 2021), epoch flag (0 = OK, 1 = power failure between current and previous epoch, >1 = special event, e.g. 2 = start moving antenna), the number of satellites in the current epoch (here 18), followed by the system identifier (G = GPS, R = GLONASS, E = Galileo, S = SBAS or geostationary) and the 2-digit satellite number (i.e. Pseudo-Random Noise

```
     2.11           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
teqc  2016Nov7                          20210617 05:02:57UTCPGM / RUN BY / DATE
Linux2.6.32-279.el6.x86_64|x86_64|gcc|Win64-MinGW64|=       COMMENT
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION       COMMENT
48DE                                                        MARKER NAME
PM183662                                                    MARKER NUMBER
NSW                 NSW                                     OBSERVER / AGENCY
1516405             LEICA GS15          8.00/7.500          REC # / TYPE / VERS
1516405             LEIGS15.R2      NONE                    ANT # / TYPE
 -4585969.9235  2736510.8223 -3477269.8581                  APPROX POSITION XYZ
        1.5190        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     6    L1    L2    C1    P2    S1    S2                  # / TYPES OF OBSERV
    30.0000                                                 INTERVAL
Source: 6405_0601_103528.m00                                COMMENT
Forced Modulo Decimation to 30 seconds                      COMMENT
DefaultJobName                                              COMMENT
DefaultUserDiscription                                      COMMENT
Project creator:                                            COMMENT
 SNR is mapped to RINEX snr flag value [0-9]                COMMENT
  L1 & L2: min(max(int(snr_dBHz/6), 0), 9)                  COMMENT
  2021     6     1     0    37   30.0000000     GPS         TIME OF FIRST OBS
    18                                                      LEAP SECONDS
                                                            END OF HEADER
```

Figure 1: Typical RINEX 2.11 header.

code, PRN, or GLONASS slot number). In this example, 8 GPS, 6 GLONASS and 4 Galileo satellites were observed.

- Line 27-28: Observations recorded for the first satellite listed (G01) – see line 13 in Figure 1 for the corresponding observation types in the RINEX header. In this example, six types of observations were recorded for all but the Galileo satellites (the L2 frequency is not used by Galileo) – L1 carrier phase measurement, L2 carrier phase measurement, L1 code measurement (C1), L2 code measurement (P2), L1 signal strength (S1) and L2 signal strength (S2). Each observation value is defined as a floating-point value of total length 14 with 3 decimals (F14.3). This is followed by two optional single-digit integer records (I1) pertaining to the Loss of Lock Indicator (LLI, range 0-7 or blank, phase observations only) and the Signal Strength Indicator (SSI, range 1-9 for increasing signal strength or blank).
- Line 29-62: Observations recorded for the other satellites in this epoch, with missing observations (or those not observed) indicated as blanks (e.g. no L2 observations to the Galileo satellites).

The interested reader is referred to Gurtner and Estey (2012) for more detailed information on the RINEX 2.11 format.

RINEX 3.04 & 3.05

Following several revisions for improvement and clarification, RINEX 3.05 (Romero, 2020) is the last official RINEX version 3 format. Its major difference compared to RINEX 2.11 is that it fully supports multi-GNSS (G = GPS, R = GLONASS, E = Galileo, C = Beidou, J = QZSS, I = NavIC/IRNSS, S = SBAS) and clearly identifies the tracking modes of each of the observations by utilising 3-character observation codes for all GNSS constellations. In particular, the possibility to track frequencies on different channels required a more flexible and more detailed definition of the observation codes.

```
 21  6  1  0 37 30.0000000  0 18G01G03G04G10G21G22G31G32R02R03R04R13
                               R18R19E05E09E11E36
 110137934.272 8  85821775.74248  20958552.220     20958554.400          53.300
        53.550
 119766659.544 7  93324688.12247  22790840.660     22790843.240          45.200
        45.100
 124156873.931 7  96745619.03746  23626267.600     23626269.980          43.200
        40.100
 130281153.04615 101517801.02255  24791680.380     24791685.800          35.450
        34.100
 107660051.087 8  83890939.09847  20487029.500     20487028.240          51.400
        45.600
 109924937.177 8  85655784.12247  20918020.040     20918017.020          52.900
        44.550
 109426889.942 8  85267704.15548  20823245.920     20823244.660          53.300
        53.250
 122182552.628 7  95207188.87447  23250567.920     23250568.700          47.650
        42.200
 122656371.420 6  95399420.181 6  22985753.460     22985758.360          38.500
        39.000
 109283847.384 8  84998559.602 8  20415141.460     20415142.640          52.450
        48.900
 114565531.929 6  89106523.251 5  21394302.360     21394302.020          38.150
        33.950
 110306911.273 6  85794276.777 7  20656940.920     20656944.020          39.850
        42.650
 114943294.330 8  89400354.336 7  21532750.260     21532755.080          50.650
        47.400
 112735465.036 6  87683135.364 6  21074705.120     21074707.020          38.950
        41.550
 129830473.839 8                  24705917.480                           48.750

 117250086.174 9                  22311949.220                           54.400

 133045175.973 7                  25317654.460                           42.450

 128710168.325 8                  24492734.840                           52.900

 21  6  1  0 38  0.0000000  0 20G01G03G04G10G21G22G31G32R02R03R04R12
                               R13R14R18R19E05E09E11E36
```

Figure 2: Typical RINEX 2.11 observation block.

Some software currently supports formats up to RINEX 3.04 only, which has minor differences to the latest version (apart from missing signals and tracking codes to fully support the 2nd and 3rd generation of Beidou). RINEX 3.04 is also the format currently being used by DCS Spatial Services for archiving CORSnet-NSW datasets and providing them to Geoscience Australia (e.g. to be used by the AUSPOS service).

The RINEX 3.04/3.05 file naming convention (Figure 3) stipulates a much longer file name than RINEX 2.11, providing more detailed information about the dataset collected by being more descriptive, flexible and extendable (this was introduced with RINEX 3.02). In particular, this facilitates the efficient storage and exchange of RINEX data in large communities like the IGS. For practical surveying applications, this naming convention may appear to be too detailed to be adopted. However, it is important that users of IGS products or CORS data understand the long RINEX file names in order to obtain the desired data for their purposes.

The following examples illustrate the benefit of the long file naming convention, with data source, start time, duration, sampling rate and data type now easily visible as part of the file name:

- BATH00AUS_R_20230501200_03H_10S_MO.rnx indicates a RINEX observation file for Bathurst CORS (being the first monument [0] and the first receiver [0, unless additional receivers are connected to the same antenna] located at this site in Australia), sourced from a receiver (via vendor or other software), observed in 2023 on day of year 050 and starting at 12:00 hours, that contains 3 hours of data at a 10-second sampling rate and mixed GNSS observation data (i.e. from at least two satellite constellations).

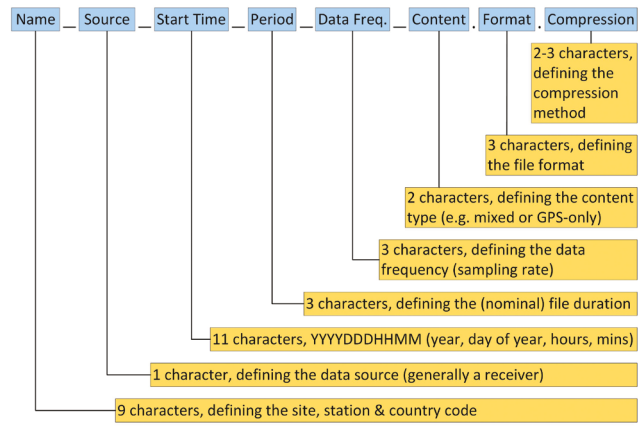

Figure 3: Philosophy of long RINEX file names introduced with version 3.02 (adapted from Gini, 2023).

- BATH00AUS_R_20230501715_15M_01S_GO.rnx also indicates a RINEX observation file for Bathurst CORS, being the first monument and receiver at this site, sourced from a receiver, observed in 2023 on day of year 050 but starting at 17:15 hours, containing 15 minutes of data at a 1-second sampling rate and GPS-only observation data.
- BATH00AUS_R_20230620000_01D_30S_MO.rnx indicates a RINEX observation file for Bathurst CORS, being the first monument and receiver at this site, sourced from a receiver, observed in 2023 on day of year 062, starting at 00:00 hours, containing 1 day of data at a 30-second sampling rate and mixed GNSS observation data.
- Accordingly, BATH00AUS_R_20230620000_01D_MN.rnx.gz indicates a compressed (the added gz extension indicates compression using the standard GNU zip, or gzip, algorithm) RINEX navigation file collected at Bathurst CORS, being the first monument and receiver at this site, sourced from a receiver, observed in 2023 on day of year 062, starting at 00:00 hours and containing 1 day of mixed GNSS navigation data.

As in the older versions, the RINEX observation file consists of a header section followed by a data section and ends with a blank line. While each row in the header continues to have a maximum length of 80 characters, this limitation has been removed for the data section (as explained below).

Figure 4 shows an example of a typical RINEX 3.04 header. It includes the following information:

- Line 1: RINEX version, specifying an observation file with mixed GNSS data (e.g. as opposed to GPS-only).
- Line 2: Program used to generate the RINEX file, who ran it (here blank) and when it was run.
- Line 3: Marker name, in this case the 4-character ID issued to NSW by Geoscience Australia.
- Line 4: Marker number, here the SCIMS number.
- Line 5: Marker type, here geodetic (i.e. an earth-fixed, high-precision monument). Selecting an attribute other than GEODETIC or NON_GEODETIC (i.e. a low-precision monument) indicates that the data was collected by a moving receiver (e.g. on a person, car, ship, aircraft, space vehicle, glacier, floating ice or even an animal).
- Line 6: Observer and agency, here indicating an organisation external to DCS Spatial Services.
- Line 7: Receiver serial number, receiver type and firmware version.
- Line 8: Antenna serial number (for integrated antennas the same as the receiver serial number) and antenna type (using the IGS naming convention).
- Line 9: Approximate site position in Cartesian coordinates (X, Y, Z) – ITRF (not WGS84) recommended.
- Line 10: Antenna height (measured vertically between ground mark and ARP) and any horizontal offset from the mark (if applicable).
- Line 11-14: For each satellite system, the number and types of observations, here specifying eight observation types for GPS, four for GLONASS, six for QZSS and four for Galileo. The 3-character observation codes include observation type (C = pseudo-range, L = carrier phase, D = Doppler, S = signal strength, X = receiver channel number), band/frequency (range 1-9) and attribute (tracking mode or channel, e.g. C, P, W, I, Q). For instance, for GPS, L1C and C1C are the L1 carrier phase and pseudo-range derived from the C/A code, while L2W and C2W are the L2 carrier phase and pseudo-range derived from Z-tracking (an effective method to acquire the encrypted P(Y) code under Anti-Spoofing conditions). This example only contains code and carrier phase measurements in order to keep the file width manageable.
- Line 15: Signal strength unit (DBHZ = signal-to-noise ratio given in dbHz).
- Line 16: Sampling interval, here 30 seconds.
- Line 17: Comment, here the raw binary data file name (can be placed anywhere between the first and last line in the header).
- Line 18-19: Time of first and last observation epoch, in this case 01:46:00 hours and 05:15:30 (GPS time) on 29 June 2023, respectively.
- Line 20: Receiver clock offset applied (0 = no, 1 = yes).
- Line 21-22: GLONASS slot and frequency numbers, indicating the number of satellites in the list followed by each satellite number and its frequency number (range -7 to +6).
- Line 23-25: Phase shift correction used to generate phases consistent with respect to cycle shifts, stated for each affected satellite system and carrier phase observation code. Here, three observation codes include a correction of -0.25 or +0.25 cycles (blank = none).
- Line 26: Number of leap seconds between GPS time and UTC, here 18.
- Line 27: End of RINEX header indicator.

```
     3.04           OBSERVATION DATA    Mixed(MIXED)        RINEX VERSION / TYPE
cnvtToRINEX 3.14.0                      20230901 041049 UTC PGM / RUN BY / DATE
35CC                                                        MARKER NAME
PM85387                                                     MARKER NUMBER
GEODETIC                                                    MARKER TYPE
EXTERNAL            EXTERNAL                                OBSERVER / AGENCY
5729470244          TRIMBLE R10         5.50                REC # / TYPE / VERS
5729470244          TRMR10          NONE                    ANT # / TYPE
 -4436326.0200  2842136.4690 -3583184.7181                  APPROX POSITION XYZ
        1.7780        0.0000        0.0000                  ANTENNA: DELTA H/E/N
G    8 C1C C2W C2X C5X L1C L2W L2X L5X                      SYS / # / OBS TYPES
R    4 C1C C2C L1C L2C                                      SYS / # / OBS TYPES
J    6 C1C C2X C5X L1C L2X L5X                              SYS / # / OBS TYPES
E    4 C1X C8X L1X L8X                                      SYS / # / OBS TYPES
DBHZ                                                        SIGNAL STRENGTH UNIT
    30.000                                                  INTERVAL
Source: 02441800.T04                                        COMMENT
  2023     6    29     1    46    0.0000000     GPS         TIME OF FIRST OBS
  2023     6    29     5    15   30.0000000     GPS         TIME OF LAST OBS
     0                                                      RCV CLOCK OFFS APPL
 12 R05  1 R06 -4 R07  5 R08  6 R09 -2 R10 -7 R15  0 R16 -1 GLONASS SLOT / FRQ #
    R17  4 R18 -3 R19  3 R20  2                             GLONASS SLOT / FRQ #
G L2X -0.25000                                              SYS / PHASE SHIFT
R L2C -0.25000                                              SYS / PHASE SHIFT
J L2X +0.25000                                              SYS / PHASE SHIFT
    18                                                      LEAP SECONDS
                                                            END OF HEADER
```

Figure 4: Typical RINEX 3.04 header.

Figure 5 shows a typical RINEX 3.04 observation data block. It contains the following information:

- Line 28: Date and time of the observation epoch (receiver time of the received signals) in the format year, month, day,

hours, minutes, seconds (here 01:46:00 hours on 29 June 2023), epoch flag (0 = OK, 1 = power failure between current and previous epoch, >1 = special event, e.g. 2 = start moving antenna), and the number of satellites in the current epoch (here 15). The special character '>' preceding the epoch information was introduced as an identifier to enable reading programs to easier detect the next epoch in case of a corrupted data file or when streaming observation data in a RINEX-like format.

- Each following line contains the observations from a single satellite, starting with the system identifier and satellite identifier (PRN). In this example, 2 Galileo, 7 GPS, 1 QZSS and 5 GLONASS satellites were observed. The previous length limitation to 80 characters per row no longer applies as this now depends on the observation type list declared in the RINEX header and the available observables per satellite per epoch.
- Line 29: Observations recorded for the first satellite (E02, i.e. Galileo satellite 02) – see line 14 in Figure 4 for the corresponding Galileo observation types in the RINEX header. Each observation value continues to be defined as a float value of total length 14 with 3 decimals (F14.3), followed by two optional single-digit integer records (I1 or blank) representing the Loss of Lock Indicator (LLI) and the Signal Strength Indicator (SSI).
- Line 30-43: Observations recorded for the other satellites in this epoch, with missing observations (or those not observed) indicated as blanks.

The interested reader is referred to Romero (2020) for more detailed information on the RINEX 3.05 format.

RINEX 4.00 & 4.01

As the necessary next step for maintaining the suitability of the RINEX format to store GNSS data and measurements into the future, RINEX 4.00 (Romero, 2021) was adopted by the IGS at the 59th Governing Board Meeting on 7 December 2021. This new version is necessary to accommodate the modernised navigation messages from all the different GNSS constellations. Once fully implemented, RINEX version 4 future-proofs the format of the navigation messages, enabling RINEX to properly store GNSS observations, navigation messages and station meteorological data files for the long-term future.

The RINEX 4.00 *observation* files are backward compatible with RINEX 3.0X and hence there is no issue in the storage and usage of RINEX 4.00 observation files. It provides a few minor extensions in observation types and extended header lines but no major format change, making adoption a minor evolution.

However, RINEX 4.00 *navigation* files are not backward compatible with RINEX 3.0X files. This is the reason why the RINEX version number was increased rather than utilising another RINEX 3.0X sub-version. But no change is necessary in file naming and storage because navigation files of all types can be stored together in different RINEX versions without any issue. All RINEX files state the version number in the first line and most reader programs will skip over unknown navigation file versions until they are ready to process them.

Development has since continued to add some necessary clarifications and new observation codes for upcoming GPS satellites and for L1 NavIC signals, resulting in RINEX 4.01 (Gini, 2023) being released in July 2023. This development has been conducted in collaboration with equipment manufacturers and software generators, ensuring that equipment and software tools able to produce and process RINEX 4.00 & 4.01 files will be available to the GNSS community in due course to enable implementation and broader adoption. More details about the RINEX version 4 format can be found in Gini (2023).

Editing RINEX observation files

Regardless of the RINEX version used, it is important to note that the RINEX header often contains incorrect or incomplete information when initially generated (e.g. the manufacturer's receiver and antenna names not following the IGS naming convention, a default antenna type or a zero antenna height), so thorough editing is very important in order to avoid confusion further down the track. This particularly applies for data archival, data sharing or submission to third parties (especially where machine-to-machine processes are likely to be employed). Ensuring the correctness of the information in the RINEX header

```
> 2023 06 29 01 46  0.0000000  0 15
E02  25294920.883 7  25294925.691 7 132925708.305 7 100557451.525 7
E25  23447480.428 8  23447484.362 8 123217340.681 8  93213132.913 8
G04  21494822.352 6                 21494825.080 5  21494829.933 7 112956049.291 6                 88017624.905 5  84350336.386 7
G07  20337145.830 7                 20337148.174 7                 106872422.420 7                 83277222.319 7
G09  20367487.010 8                 20367490.340 7  20367494.468 8 107031866.687 8                 83401469.315 7  79926420.520 8
G14  23881998.475 6                 23882004.464 7  23882010.066 7 125500746.909 6                 97792815.156 7  93718137.735 7
G20  23898920.072 6  23898925.616 3                                125589663.277 6  97862096.929 3
G27  23825218.979 5                 23825219.068 4  23825223.775 6 125202379.199 5                 97560279.945 4  93495301.251 6
G30  22227137.499 7                 22227142.425 6  22227146.437 8 116804390.872 7                 91016432.610 6  87224096.414 8
J07  37434047.147 6  37434051.555 7  37434054.257 7 196717240.891 6 153286182.977 7 146899267.577 7
R05  19811646.971 7  19811650.783 6 105904612.687 7  82370142.314 6
R06  20261919.814 6                 108121477.98516
R09  22436373.073 7  22436380.500 7 119808978.418 7  93184773.342 7
R15  21016941.129 7  21016946.524 7 112308166.088 7  87350586.238 7
R16  19461669.657 8  19461674.685 7 103960753.501 8  80858379.014 7
> 2023 06 29 01 46 30.0000000  0 16
```

Figure 5: Typical RINEX 3.04 observation block.

is not only good practice but also very valuable when mining data for purposes that were not envisaged when the data was originally collected.

The RINEX format stipulates the antenna type as a 20-character name (see columns 21-40 of line 9 in Figure 1 and line 8 in Figure 4), including several spaces and ending with a 4-character indication of the radome (antenna cover) used (NONE meaning that no radome is present). The authoritative source for resolving antenna queries are the frequently updated IGS files *rcvr_ant.tab* and *antenna.gra* (IGS, 2023c).

The file *rcvr_ant.tab* details the international naming conventions for GNSS receivers, antennas and radomes, which are also used by online processing services such as AUSPOS. The file *antenna.gra* provides graphs with physical dimensions of GNSS antennas, including the position of the ARP (generally the bottom of the antenna) and vertical offsets to other features such as the centre of bumper or bottom of choke ring. As an aside, the file *igs20.atx*, containing the IGS antenna models recommended for baseline processing, can be found at the same location (it is frequently updated to include new antennas). If still in doubt, users should contact their equipment provider for the required antenna information.

If the antenna height was not measured directly and vertically to the ARP in the field, e.g. when using a vertical height hook measurement or a slant measurement to the bumper or the Slant Height Measurement Mark (SHMM) on the instrument, then it must be converted to the vertical distance between the ground mark and the ARP using the offsets and method (generally applying Pythagoras in conjunction with a vertical offset) specified in the GNSS equipment manual or provided by the manufacturer – see Janssen and McElroy (2022) for examples.

The correctness of antenna height and antenna type is crucial to allow the correct antenna model to be applied correctly in processing. An incorrect antenna type can introduce significant bias (more than 10 cm in the vertical component) and noise into the computed coordinates. An error in the antenna height will directly translate into an error in the resulting GNSS-derived ellipsoidal height and thus the derived physical (orthometric) height.

If session length is critical to contractual arrangements and/or data acceptance by a third party, it is recommended to always extend session lengths by a few minutes. The start and end of the GNSS observation section in the RINEX file should be visually inspected, particularly to ensure that the first and last few epochs contain reasonably complete data blocks. If epochs at the start/end of the observation are deleted, the time of the first/last observation in the RINEX header should be modified accordingly.

Frequent dropouts of satellite signals from epoch to epoch in the RINEX file may indicate bad data quality due to poor sky view conditions (e.g. tree cover or other obstructions). A longer observation session generally improves processing results in this regard. Note that the raw observation files in their native (binary) proprietary format collected by the GNSS receiver are compact and should always be permanently archived – they can be re-converted to RINEX and edited again if required.

Conclusion

The widely used RINEX format is the international standard for the storage and exchange of GNSS data. It allows efficient and unambiguous archiving of GNSS data and associated metadata in one place, while also facilitating the easy transfer and distribution of such data, independent of the equipment used and the data processing software employed. Over the years, and through several versions and sub-versions, the RINEX format has continually been improved and expanded to cater for modern satellite positioning data collected by a growing number of satellite constellations and their signals.

This paper has presented a brief history of the RINEX format and explained recent RINEX format versions using examples relevant to the surveying profession. This included outlining the short and long RINEX file naming conventions and the editing of RINEX observation files to ensure correctness of the header information. It is hoped that this contribution has helped the surveying profession to better understand the RINEX format, the philosophy behind it, and its benefits to users.

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Who am I?

I was conceived in 1973, in the lonely halls of a government building in North America.

I have a loving father and many uncles, all of them very smart but not known to the general public.

I am not your average person. I'm everywhere but invisible to the naked eye.

First it was just me, then I had a troubled brother. Now I have several siblings. We don't always see eye to eye, but we do work well together for the benefit of all.

I didn't have an easy childhood, but now I'm living the American dream... from humble beginnings to world domination.

I have a huge ego and enjoy telling people where to go.

They say that money makes the world go round, but really it is me because my timing is so good.

I was embraced during the 1st Gulf War and have never looked back.

As I grew more mature, I lost weight and now I fit into almost anything.

This year I'm celebrating my golden jubilee... and I'm not done yet. I'm here to stay. I love being sky-high and on top of the world.

I am GPS.

Dr Volker Janssen
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The ubiquitous dimensions of surveying and mapping deliverables in Nigeria

In Ubiquitous dimensions, the notion of a "map" must be replaced with "mapping," as users demand real-time creation and manipulation of maps in a digital society

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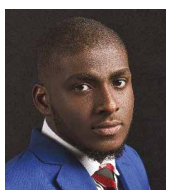

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Abstract

Ubiquitous dimension of surveying and mapping refers to the utilization of surveying and mapping deliverables or environment to create maps for various sectors of the economy to resolve spatial problems. Harnessing the following basic elements; the real world, the map or mapping environment, the user, and the information technology (IT) infrastructure in a human-oriented context that emphasizes the interaction between the output map and map user's responses such as spatial cognition and decision making. This dimension emphasizes the interaction between output maps and user responses, such as spatial cognition and decision making. In Ubiquitous dimensions, the notion of a "map" must be replaced with "mapping," as users demand real-time creation and manipulation of maps in a digital society. Mapping deliverables could be of any of the following dimension (2D, 3D, and 4D), as well as common spatial articulation and categorization of the objects mapped.

Introduction

A surveyor is a professional with requisite the academic qualifications and technical expertise to practice the science of measurement, to assemble and assess land and geospatial related information for the purpose of planning and implementing the efficient administration of land, the sea and structures thereof (Ejiobih, 2008) while Surveying as the act and science of determine the location, size and shape of parcel of land, and other relevance information about the area (Kolawole, 2006). In today's digital era we have definitions such as "Surveying being the capture, processing, analysis, presentation and the management of Geo-Spatial information (Ayeni, 2015). In Nigeria, the Surveyors Council of Nigeria (SURCON) is the regulatory body responsible, by law, for the certification of Surveyors. The use of Geospatial information is increasing rapidly. There is a growing recognition amongst both government and the private sectors that the understanding of location and place is a vital component of effective fact- based decision making. As it is said "Everything happens somewhere" because location matters, it is also concluded that Surveying is Ubiquitous. Listed below are some of the needs of its to some MDA's.

Mapping technology has significantly transformed various sectors, including administration, agriculture, archaeology, communication, and education. Line maps provide topographic and boundary information for boundary demarcation and constituency delimitation, improving political and administrative relationships. The integration of mapping tools and Geographic Information Systems (GIS) has led to profound impacts on decision-making, resource allocation, governance, and public engagement. Mapping tools have a comprehensive view of complex issues, empowering citizens and standing as a testament to its transformative potential.

In **administration**, there is a need to have map(s) that clearly outlines the boundaries of each country, state, district, constituency, local government area (LGA) and ward. Line maps are produced to maintain the

relationship between nations, states and LGAs, provide adequate topographic and boundary information to aid in boundary demarcation for the related places and also in constituency delimitation issues which goes a long way in improving both political and administrative relationships either internationally, interstate or in LGAs. As governments continue to harness the power of spatial information, the impact of mapping tools on shaping policies, enhancing resource allocation, and fostering public engagement will undoubtedly remain profound.

In **agriculture,** modern farming practices have evolved dramatically, thanks to cutting-edge technologies that optimize crop production, conserve resources, and ensure food security for a growing national population. At the heart of this transformation lies surveying and mapping information that empowers farmers to make data-driven decisions, hence farmers no longer toil blindly across their fields. As we confront the challenges of a changing climate and a growing global population, the role of surveying and mapping information in agriculture becomes ever more vital. It is a powerful tool that ensures we can feed the world sustainably while protecting the environment for generations to come.

In **archaeology**, mapping plays a crucial role in dereferencing historical locations, research, and tracking artifacts. Mapping has expanded the range of archaeological questions and facilitated collaboration across disciplines. In **communication**, mapping plays a critical role in the distribution, location, and management of communication lines and facilities. The convergence of mapping technology with communication tools has created a dynamic synergy, reshaping the way we understand, navigate, and share spatial information. In **education**, mapping plays a critical role in the development of a nation's curriculum, enabling students to access digital information and navigate the physical world. Overall, mapping technology has transformed various sectors, including education, government, agriculture, and communication.

In **environmental** studies, the significance of surveying and mapping in addressing the nation's most pressing issues cannot be overstated. These technologies have proven to be invaluable tools in the realm of environmental management, providing critical data and insights to guide conservation efforts, resource management, and disaster preparedness. For constructing infrastructure projects like roads, bridges, and pipelines, environmental surveys and mapping are conducted. These assessments help identify potential environmental impacts and design mitigation measures to minimize harm to ecosystems. The monitoring Surveying and mapping also enable us to monitor shifts in land cover, sea levels, and temperature patterns, provide valuable insights into the health and potential threats facing renewable resources such as forests, water bodies, agricultural land. The nations quest to preserve and protect our environment, surveying and mapping technologies have emerged as an indispensable ally in understanding climate change and it's impacts hence developing strategies for adaptation and mitigation. As we navigate the complexities of our ever-changing world, these technologies remain essential tools in our pursuit of a greener and more sustainable environment that policymakers and land managers can make informed decisions, protecting and preserving these irreplaceable assets for future generations.

In **finance**, mapping helps track and monitor revenue generation from various sectors, such as tax collection, customs, immigration, and health. It transforms complex data into actionable insights, aids decision-making, enhances risk management, and fosters innovation. Mapping has revolutionized the finance sector by offering powerful visual tools for analyzing, interpreting, and communicating complex financial information. In **forestry**, mapping is essential for inventory, change detection, and timber production. It provides detailed insights into forest composition, structure, and dynamics, facilitating informed decision-

Table 1: Some sectoral usage of surveying and mapping information

Sectoral application	Typical usage of survey and mapping information	Digital geodata required
Administration	International, Interstate and LGA boundary demarcation, consistency delimitation	LM, TM
Agriculture	Cultivation Inventory, Vegetation cover, Soil Study, River dams, and Irrigation, Land use crop yield monitoring, marine resources	LM, TM
Archaeology	Georeferencing of historical locations, research study etc.	LM
Communication	Distribution and location of communication lines and facilities, Distribution and location of postal services, Road network services and coverage	LM
Education	Facilities planning, instruction/ learning aids, location or institution	LM, TM
Environment	Rick zone mapping, Environmental inventory and monitoring, Desertification, Flood and erosion monitoring, land degradation, environmental impact assessment, costal monitoring.	LM, TM
Finance	Revenue generation, Taxation, Customs and Immigration.	LM
Forestry	Forestry mapping, Forestry Inventory, change detection, Forest Development and timber Production for export and domestic uses	TM, LM
Geology	Photo-geology, Reconnaissance, Soil study, Soil mineral exploration, exploration distribution, marketing, monitoring	LM, TM
Governance	Taxation, Land use, new town development, utility services Tenement Rates, Licenses, Boundary Administration, Road Main etc.	LM, CM
Health	Epidemic location, prevention and forecasting, facilities planning, Management and distribution, Orthopedic measurement	LM
Petroleum	Oil and Gas exploration, Exploration, Distribution, Marketing and Monitoring	LM, TM
Planning	Urban and regional planning, Urban renewal and change studies, feasibility studies, Land use mapping, Land administration, location of industries	LM, TM, CM
Population Census	Planning, Enumeration areas, demographic studies and analysis	LM
Power generation and distribution	Power distribution network location, facilities distribution, location and maintenance customer location and revenue collection	LM
Security	Defense, Crime Prevention and Monitoring, Search and Rescue, Vehicle Tracking	LM, TM
Sports	Facilities planning, development and management	LM, TM
Tourism	Road network maps and street guides, Tourism center and Hotel Location	LM, TM
Transport and Aviation	Roads and Airport Runaway design, railway design, Aeronautic charts for navigation, search and rescue operation, Traffic planning and monitoring	LM, TM
Water Supply	Facilities distribution and location, pipeline distribution, location and Management Customer enumeration and revenue collection.	LM

CM = Cadastral Maps: Contains Land Parcel, Identifier, Ownership and land use.
LM = Line Maps: Contains topographical, road, utilities, boundary and administrative layers at various scales.
TM = Thematic Maps: Customized for specific purposes. They include Topographical, Geological, Land Use/ Land Cover, Vegetation, Mineral and Soil Maps at various scales.

making, resource management, and environmental conservation. As technology evolves, mapping in forestry will continue to improve, with advancements in satellite imagery, LiDAR technology, and artificial intelligence enhancing data collection and analysis capabilities. Mapping remains an indispensable tool in ensuring the health, resilience, and longevity of forests.

In **geology**, Mapping plays a crucial role in soil mineral analysis by providing valuable insights into the Earth's composition, structure, and history, enabling scientists to understand geological formations, identify mineral deposits, predict natural hazards, and make informed land use decisions. Mapping techniques have a significant impact on economic development, natural hazard mitigation, and ecological conservation. In **governance** at the lowest tier Nigeria has 774 local government areas that uses line and cadastral Maps for planning, implementing, and monitoring tax duties, utility services, and infrastructures. These maps aid in decision-making, resource allocation, urban planning, and citizen engagement. Mapping technology has also transformed the **health sector**, revolutionizing disease surveillance, resource allocation, and healthcare access. By harnessing geographical information, the health sector has become more proactive, data-driven, and capable of addressing health challenges on a broader scale.

In the **petroleum** sector has seen a significant transformation due to the extensive use of mapping technologies. Mapping has transformed exploration, production, and management of petroleum resources, enhancing resource recovery, profitability, and sustainability. The sector's future will be shaped by these technologies, which not only enhance resource recovery and profitability but also enable responsible and sustainable operations in an ever-changing global landscape. In **planning**, maps serve as visual tools that enable planners to analyze, communicate, and make informed decisions about spatial relationships and resource allocation. Recall that planning, the art of anticipating change and balancing economic, social, political, and physical forces, relies heavily on maps for urban and regional development. The integration of mapping technology into planning enhances efficiency, accuracy, and overall quality of outcomes in diverse sectors. The combination of spatial data analysis and visual representation empowers planners to create sustainable, resilient, and well-designed urban landscapes.

In **population** studies, mapping plays a crucial role in this sector, ensuring accuracy, efficiency, and equitable resource distribution. Since population census is a crucial process for a nation's statistical system, providing demographic, economic, and social data. Mapping improves the reliability of census data, informs governance, planning, and development, and leads to more informed decision-making (United Nations, 2008). In the **power generation and distribution** sector, mapping technologies have revolutionized the operations of the Power Holding Company of Nigeria (PHCN), formerly National Electric Power Authority (NEPA), and the Nigeria Electric Regulatory Commission (NERC). This has led to improved infrastructure management, enhanced customer service, data-driven decision-making, and better disaster preparedness, ultimately contributing to a more reliable and efficient power supply for Nigeria's residents and businesses.

In national **security**, maps give the security unit the ability of a sovereign state to protect and defend its citizens, including crime monitoring, prevention, search, rescue operations, and tracking thefts (Osisanya, ND). To achieve this, a state must have an up-to-date Line Map of its jurisdiction. Advancements in technology can make government surveillance more effective, and solutions like district wide-view drone-based camera systems can help protect rail lines and pipelines. Collaboration between military and security agencies and the Office Surveyor General of the Federation is crucial for generating geospatial intelligence for effective utilization by authorities. Maps are essential tools in security, providing valuable information, aiding planning, enhancing situational awareness, and facilitating communication for various security-related purposes. By leveraging geospatial data, security agencies can enhance their effectiveness, minimize risks, and protect people and assets more efficiently.

Sports in the leisure and recreation sector can contribute to the GDP of Nigeria if well managed. A Line map showing topographical, road, and utilities at various scales is required for decision-making and finding suitable areas for facilities installation. Mapping technology has significantly transformed the sport development sector, enhancing player performance analysis, tactical strategies, injury prevention, fan engagement, scouting, venue management, training, referee support, and broadcast coverage. As technology advances, mapping's impact on the sports industry is likely to evolve further, leading to more sophisticated applications and enhanced experiences for all stakeholders.

Tourism is a lucrative industry that significantly impacts the economy and social context of countries, fostering the development of other sectors through a multiplier effect. It encompasses activities, facilities, services, and industries that provide travel experiences, including transportation, accommodation, entertainment, recreation, and destination attractions (Fadahunsi, 2011). Surveyors play a crucial role in providing accurate and precise maps of tourist areas, aiding in planning and developing tourist destinations, infrastructure, and facilities. These maps provide information about terrain, land use, elevation, and other features, enhancing visitor experiences and ensuring responsible development of tourist destinations.

Transportation and aviation sectors are crucial for a nation's GDP and require continuous survey data production. Maps are needed for planning, location, and construction of roads, airports, railroads, and maintenance. Mapping technology has transformed these sectors by making travel safer, more efficient, and environmentally conscious. Advanced navigation systems and accurate mapping data enable pilots to navigate through complex airspace, make informed decisions during takeoff, landing, and mid-flight, and design road networks, public transportation routes, and city layouts. **Water Supply** depends solely on mapping technology because it aids the management and provision of clean water, enhancing efficiency, decision-making, and resource management. The integration of

spatial data and analytics empowers water corporations to operate more efficiently, make informed decisions, and contribute to sustainable water management practices.

Conclusion

The public and private sectors are facing significant geo-spatial needs due to the large investments involved in petroleum products and cement. As location matters and the numerous factories and construction sites require geo-spatial information, the ubiquitous dimensions of surveying and mapping deliverables are crucial and essential for efficient use in these industries. In most cases, the end product of survey works is a map. It could be either line map, cadastral map or thematic map or a combination of two or all the maps.

Therefore, the nature or type of information to be extracted is what determines the type of map production or combination. Hence, the importance of survey in every sector to harness both human and material resources while monitoring the finance and growth of the sector can never be over emphasized. As such the use of surveyors in the different sectors should always be considered and given priority as the results gotten is what determines to a great extent how such sector can grow while also adapting to the changing times and conditions.

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Ligado Networks sues U.S. Government

Mobile communications company Ligado Networks has sued the U.S. government for its unlawful taking of Ligado's constitutionally protected, exclusively licensed spectrum without compensation.

Backed by a multiyear misinformation and disparagement campaign against Ligado to conceal these activities, the U.S. government misappropriated Ligado's exclusively licensed spectrum to support previously undisclosed Defense Department systems that have been using Ligado's spectrum without permission.

The Federal Communications Commission (FCC) exclusively granted the company rights to use this spectrum after a comprehensive, multiyear regulatory review process. In good faith reliance on the FCC's order, Ligado raised and invested billions of dollars to prepare its spectrum to support next-generation terrestrial 5G services.

The lawsuit, filed in the U.S. Court of Federal Claims against the United States, the Defense Department, the Commerce Department and NTIA, seeks just compensation for the government's physical, categorical, regulatory and legislative takings of Ligado's property. *ligado.com*

EU finalizing contract with SpaceX for Galileo launches

The European Union is in the final stages of completing a deal with SpaceX to launch four Galileo navigation satellites in 2024.

In press briefings during the European Space Summit in Seville, Spain, Nov. 7, Thierry Breton, commissioner for the internal market for the European Commission, said he was "finalizing the discussions" for a pair of Falcon 9 launches, each carrying two Galileo satellites, tentatively scheduled for April and July of 2024.

The last obstacle to completing a launch contract, he said, was negotiating a security agreement to protect sensitive technologies on the Galileo satellites, which previously had been launched from the European spaceport in French Guiana, when those satellites are being prepared for launch from the United States.

The launch contract itself was completed in July, Breton noted, and that the European Commission had approved a European Space Agency proposal to use the Falcon 9 for launching those satellites. He said the European Commission would spend 180 million euros ($192 million) on the Falcon 9 launches. *spacenews.com*

Geode GNSS receiver by Juniper Systems

Juniper Systems, Inc., is excited to announce its Geode™GNS3M (multi-frequency) GNSS Receiver will now support RTK Fixed position capability. The receiver allows users to easily collect real-time GNSS data with sub-meter, sub-foot, decimeter, and now centimeter accuracy options. With the addition of the Hemisphere® GNSS Athena™ RTK Engine, Geode users will have access to the full spectrum of professional-grade mapping accuracies once RTK is activated. This scalable platform allows users to purchase the level of accuracy they need now while having the option to increase accuracy in the future. *junipersys.com*

Maxtena GNSS L1/L2/L5 tactical grade antenna

Maxtena has introduced a new GNSS L1/L2/L5 tactical grade antenna. The new M10HCT-TNC antenna will offer concurrent GNSS reception covering all L1/L2/L5 GPS, Galileo, Glonass, and Beidou bands including L-Band correction. Antenna housing is in an IP67 rugged, compact, and ultra-lightweight form factor. M10HCT-TNC is designed to meet MIL-STD-810 requirements and highlights cutting-edge technology and is designed to work in high RF noise environments. *www.maxtena.com*

Neuraspace and Arcsec partner for debris detection

Neuraspace, a provider of space traffic management (STM) has partnered with Arcsec, a provider of star trackers to develop a new way to detect space debris.

Neuraspace will harness Arcsec's space-based star trackers for detection and characterisation of space debris and resident space objects. Arcsec's trackers use optical sensors onboard their satellites to determine spacecraft attitude. The brightness information about space objects from these star trackers provides crucial insights into the size of detected debris. Additionally, they have reprogrammable capability in orbit, so already-launched sensors can be enhanced with space situational awareness (SSA) functionality. *www.neuraspace.com*

Object Computing, Planet Labs partnership

Object Computing, Inc has announced a partnership with Planet Labs PBC, to harness the power of geospatial data insights for enterprise businesses across industries. *https://objectcomputing.com*

Open Cosmos satellites successfully launched

Latest two satellites, MANTIS and PLATERO, of Open Cosmos have successfully reached orbit following the launch of the SpaceX Transporter-9 mission at Vandenberg Space Force Base, California, US.

Both satellites will join MENUT launched earlier this year as part of the OpenConstellation, a global, shared Earth Observation satellite infrastructure built and managed by the company.

Data collected from OpenConstellation satellites can be accessed by organisations and businesses of all sizes, as well as national and regional governments to address challenges around the climate crisis, energy, natural resources and more. *www.open-cosmos.com*

UP42, GLOBHE sign partnership

UP42 and GLOBHE have announced their partnership to make high-quality drone data available through UP42. GLOBHE relies on 9500+ local professional drone operators in 142 countries and is the sole drone marketplace platform to support automated data collection at a global scale for sustainable infrastructure, environmental and humanitarian purposes. *https://up42.com*

Remotely fly X10 drone from a browser

Skydio Remote Flight Deck, a new offering that enables remote flight for Skydio X10 drones via a browser, anywhere over a cellular network. The solution offers a seamless handoff of flight control between local and remote pilots, allowing for fluid operations and uninterrupted situational awareness through live streaming. For the first time, operators can launch or control drones within their organization from virtually any location outdoors or indoors. *www.skydio.com*

CHC Navigation introduces the AlphaAir 10

CHC Navigation has introduced the AlphaAir 10 (AA10), an innovative airborne mapping system that seamlessly integrates high-precision LiDAR technology, accurate GNSS positioning, IMU orientation, and an industrial-grade full-frame orthophoto camera.

The AA10 features a lightweight, compact design and effortless compatibility with a wide range of UAV platforms. It can detect up to 8 target echoes utilizing advanced multi-target capabilities, greatly enhancing its ability to penetrate dense vegetation and acquire precise ground surfaces. *https://chcnav.com*

DroneShield launches of SensorFusionAI

SensorFusionAI (SFAI), a sensor-agnostic, 3D data fusion engine for complex environments. DroneShield has developed a true AI-based sensorfusion engine, initially for its own DroneSentry-C2 command-and-control system, including all common drone detection modalities (RF, radar, acoustics, camera). This separation enables third party C2 manufacturers (including primes) to add SFAI to their C2 systems, on a subscription basis (SaaS), thus improving the performance. *www.droneshield.com*

The FAA authorizes Phoenix Air Unmanned to operate BVLOS

The FAA authorized Phoenix Air Unmanned to operate SwissDrones SVO 50 V2 drones beyond visual line of sight (BVLOS)for aerial work, aerial photography, survey and powerline and pipeline patrol and inspection. The FAA issued the approval after asking for public input on four BVLOS requests, including from Phoenix Air Unmanned. The agency is reviewing the other three requests. Data collected from these operations will inform the FAA's ongoing policy and rulemaking activities.

The FAA is focused on developing standard rules to make BVLOS operations routine, scalable and economically viable. The agency chartered the Beyond Visual Line of Sight Aviation Rulemaking Committee on June 9, 2021 to provide safety recommendations to the FAA. *www.faa.gov*

Vigilant Aerospace to develop Detect-and-Avoid System

Vigilant Aerospace Systems, Inc., has been awarded a contract by the US Air Force to develop a detect-and-avoid system for the Air Force's new long-endurance drone. The objective of the project is to "integrate a mature detect and avoid capability on an existing long-endurance, Group V UAS platform for increased aircraft and pilot-in-the-loop operational awareness that leverages new and evolving C-SWaP sensors and sensor fusion software." The project is sponsored by the Air Force Research Lab (AFRL) and is an SBIR Phase II project through the SBIR program. The program seeks to bring dual-use technologies, which can help both civilian and military users, into the military, with a focus on high-impact, near-term implementations. *https://vigilantaerospace.com*

Trimble introduces MPS566 Modular GNSS heading receiver

Trimble has announced its next generation GNSS receiver for marine construction and drilling and piling operations—the Trimble MPS566 Modular GNSS heading receiver. With built-in dual GNSS antenna ports and constellation-agnostic Trimble ProPoint™ technology, the MPS566 delivers highly accurate positions and orientation for work that demands precise heading. With a ruggedized and compact form factor, the MPS566 consumes low power and has minimal cabling, all benefits when installation space is at a premium. *www.trimble.com*

VectorNav releases two new INS

VectorNav Technologies, has announced the development of two new products, the VN-210-S and VN-310-S, to expand the company's tactical series of GNSS-aided Inertial Navigation Systems (INS).

The VN-210-S GNSS/INS combines tactical-grade IMU comprised of a 3-axis gyroscope, accelerometer, and magnetometer with an all-new triple-frequency GNSS receiver. The VN-310-S Dual GNSS/INS leverages tactical-grade IMU and integrates two 448-channel GNSS receivers to enable GNSS-compassing for accurate heading estimations in stationary and low-dynamic operations. *www.vectornav.com*

SBG Systems' Qinertia and HxGN SmartNet join forces

SBG Systems, a leading provider of inertial navigation solutions, and Hexagon, a global leader in positioning and mapping technologies, are excited to announce their collaboration to offer improved accuracy and seamless integration for mapping applications.

Qinertia, developed by SBG Systems, is a powerful post-processing software. It is designed to enhance the location data accuracy by combining INS measurements with GNSS location and correction data. Its exclusive algorithms allow to achieve centimeter-level accuracy. The recent launch of Qinertia 4 can now leverage the power of HxGN SmartNet's 5000 reference stations mainly across North America, Europe, and Asia-Pacific regions. *www.sbg-systems.com*

FJDynamics launches new guidance and steering solutions

FJDynamics has launched their Guidance and Steering Solutions, featuring the AH1 Hydraulic Autosteering Kit and AG1 Guidance System. The new solutions provide farmers with exceptional precision and consistency in steering, resulting in perfectly straight crop rows and optimal use of resources. *www.fjdynamics.com*

Point One Navigation joins STMicroelectronics partner program

Point One Navigation has joined the STMicroelectronics Partner Program to deliver reliable navigation and positioning solutions for a diverse spectrum of ST customers in the US and Western Europe. By implementing Point One's proven navigation software and RTK network, developers using ST Teseo GNSS Solutions now have a quicker and easier path to create the industry's most accurate precision navigation solutions. *https://pointonenav.com*

Pasternack introduces cutting-edge IoT multiband antennas

Pasternack introduces its state-of-the-art IoT multiband combination antennas. The latest from Pasternack's innovation lab integrates the potency of 4G, 5G, Wi-Fi and GPS bands within a singular, sleek radome. This harmonious fusion ensures that emergency teams, on-the-move fleets and first responders can guarantee an unwavering link, no matter where duty calls. *www.pasternack.com*

Septentrio broadens its ecosystem with new open-source projects

Septentrio introduced two new open-source hardware projects available to integrators of satellite-based positioning. The new projects embed mosaic, a compact high-precision multi-frequency GPS/GNSS receiver module known for its robust performance and resilience to jamming and spoofing.

The first project, mosaicBus, is a reference design of a board compatible with mikroBUS™, one of the world's fastest-growing add-on board standards primarily used in embedded systems. It enables easy plug-and-play sensor integration and is designed into development boards of major vendors including MikroElektronika, the company that developed the mikroBUS™ standard. The second project, called mosaicAlto, is a carrier board embedding the mosaic-X5 or mosaic-H GNSS receivers, which transforms Arduino Pro "Portenta" into a single-board computer with a GPS/GNSS receiver. Septentrio.com

EMCORE Introduces New TAC-440 MEMS IMU

EMCORE Corporation has announced the introduction of the TAC-440 MEMS Inertial Measurement Unit (IMU), the world's smallest 1°/hour IMU. It is a higher-performance, form fit, and function compatible replacement for the Honeywell 1930 and 4930 IMUs. It's breakthrough performance is based on EMCORE's proven quartz MEMS inertial sensor technology. *emcore.com*

Adtran launches satellite time and location solution

Adtran has launched new synchronization solutions featuring Satellite Time and Location (STL) technology to address the growing vulnerabilities of GPS and other GNSS systems to jamming and spoofing attacks.

Alongside GNSS-based timing, the OSA 5405-S PTP grandmaster clock can now receive STL signals. This compact and versatile device caters to a diverse range of indoor and outdoor deployment settings, serving industries from 5G and data centers to smart grids and defense. *www.adtran.com*

Eos Positioning Systems Receives Mobile GIS Award

Eos Positioning Systems, Inc., received the Mobile GIS Award at the 2023 Esri Infrastructure Management and GIS concluded recently. Eos serves utilities; local governments; AEC firms; and transportation organizations with easy-to-use and precise GNSS receivers and solutions that pair seamlessly with Esri mobile apps. *https://eos-gnss.com*

Survey to improve precise positioning through SouthPAN seeks OEMs

The Australian and New Zealand governments, with support from FrontierSI, are conducting a survey with OEMs to identify the opportunities and barriers for integrating Southern Positioning Augmentation Network (SouthPAN) signal support in GNSS chips, devices and equipment.

SouthPAN is a Satellite-Based Augmentation System (SBAS) in the Southern Hemisphere and provides improved positioning and navigation services in Australia, New Zealand and maritime regions.

Precise positioning from the network offers improved accuracy down to 10 cm. SouthPAN provides augmented and corrected satellite navigation signals directly from the satellite rather than through a mobile phone, providing accuracy that overcomes gaps in mobile internet and radio communications. Its early Open Services has been live since September 2022, and aviation safety-of-life certified SouthPAN services are set to go live in 2028. Safety-of-life certified services are designed to support end users engaging in life risking operations, such as landing an aircraft at an airport.

OEMs of positioning and/or navigation service equipment are asked to share insights on the support of SouthPAN's three services into chips, devices and equipment. In particular, the company is looking for OEM's' views on barriers and opportunities for support of the L1, dual frequency multi-constellation (DFMC) and precise point positioning (PPP) via SouthPAN services. *www.ga.gov.au*

LocLab launches cloud tech for 3D digital twin accessibility

LocLab, part of Hexagon launched LocLab Cloud, powered by HxDR. It offers a secure end-to-end solution for 3D digital twins, allowing management and monitoring of models. It specialises in developing object-based and structured digital twin models that seamlessly integrate data from various systems and sources. *www.loclab-consulting.com*

New multibeam echosounder by Kongsberg

Kongsberg Discovery has officially unveiled the EM 2042, a next-generation multibeam echosounder. With the capability to extend operational weather windows, it empowers users in their quest to comprehend, safeguard and harness the ocean's depths. It has lightweight design, easy installation, robustness and the capacity to gather pristine seabed data even in the most remote and challenging environments. *www.kongsberg.com*

Leica Geosystems upgrades lidar UAV

Leica Geosystems has added new capabilities to the Leica BLK2FLY. It now has the ability to scan indoors, providing expanded coverage for complex scanning projects, and the ability to create digital twins for entire structures, both indoors and outdoors.

Smart UAV survey software

Virtual Surveyor has added UAV photogrammetry capabilities to its Virtual Surveyor smart UAV surveying software. The new Terrain Creator app photogrammetrically processes UAV images to generate survey-grade terrains which then transfer into the traditional Virtual Surveyor workspace. It was originally developed to bridge the gap between UAV photogrammetric processing applications and engineering design packages. *www.virtual-surveyor.com*

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February 2024

Geo Week 2024
11 - 13 February
Denver, CO, USA
https://www.geo-week.com

MENA Geospatial Forum
14 - 15 February 2024
Dubai, UAE
https://menageospatialforum.com

March 2024

Geo Connect Asia
06 - 07 March 2024
Singapore
https://www.geoconnectasia.com

DGI 2024
11 - 13 March
Londone, UK
https://dgi.wbresearch.com

Munich Satellite Navigation Summit 2024
20 - 22 March
Munich, Germany
www.munich-satellite-navigation-summit.org

April 2024

GISTAM 2024
02 - 04 May
Angers, France
https://gistam.scitevents.org

IGRSM Conference 2024
29 - 30 April
Kuala Lumpur, Malaysia
https://conference.igrsm.org

May 2024

FIG Working Week 2024
19 - 24 May
Accra, Ghana
www.fig.net/fig2024/Welcome.htm

June 2024

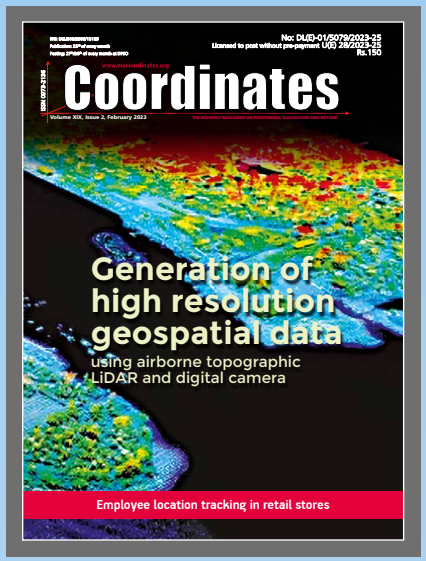
GEO Business 2024
05 - 06 June
London, UK
https://www.geobusinessshow.com

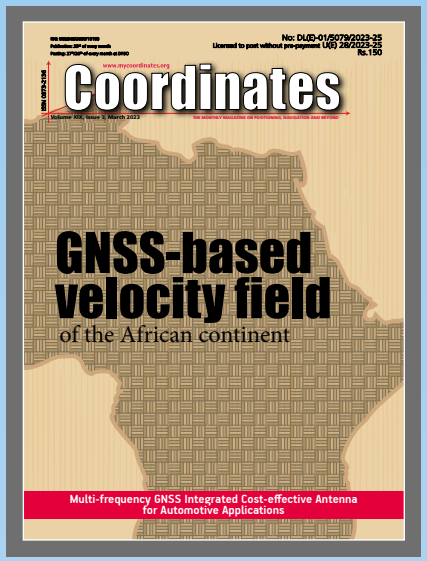
July 2024

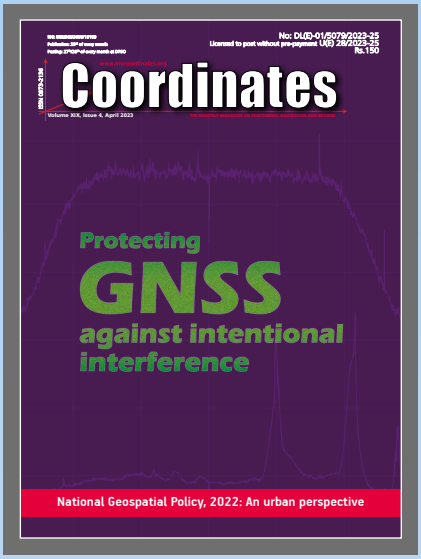
Esri User Conference
15 - 19 July 2024
San Diego, CA, USA
www.esri.com

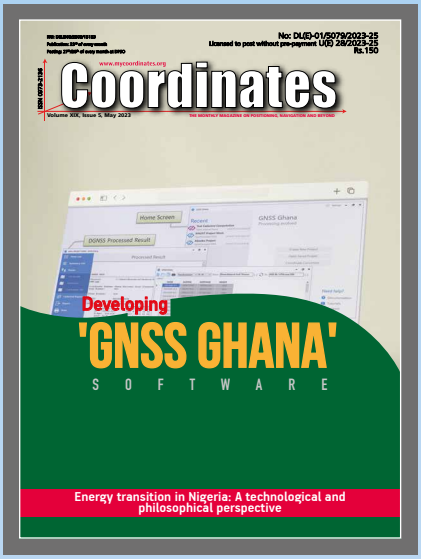
August 2024

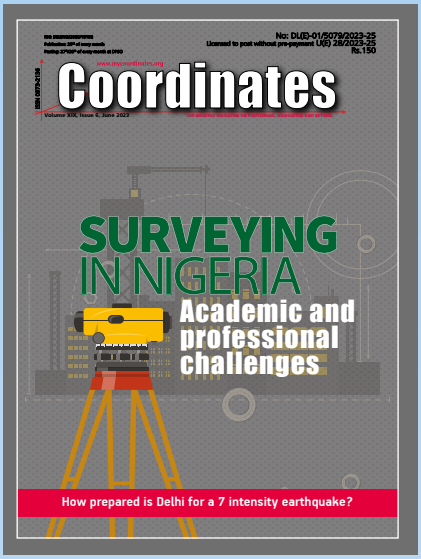
International Geographical Congress 2024
24 - 30 August
Dublin, Ireland
https://igc2024dublin.org

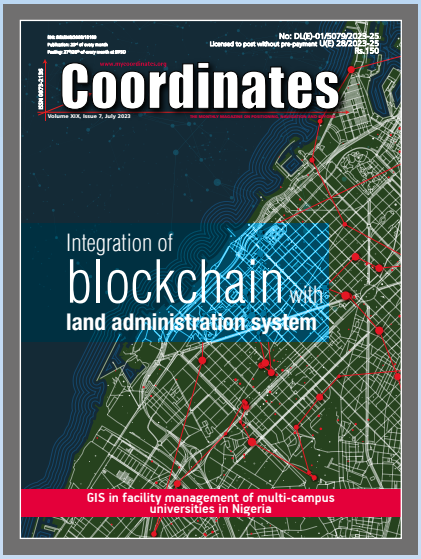


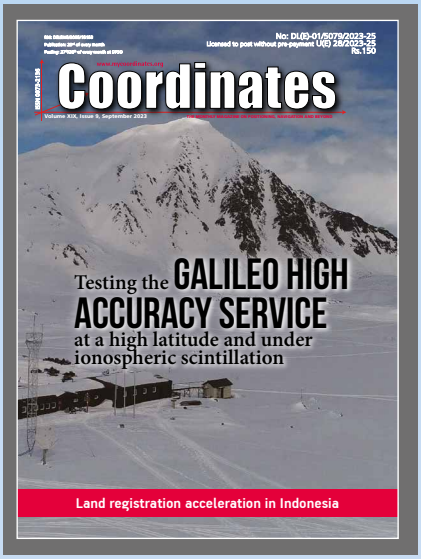












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