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THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

Mapping of the Mount Everest

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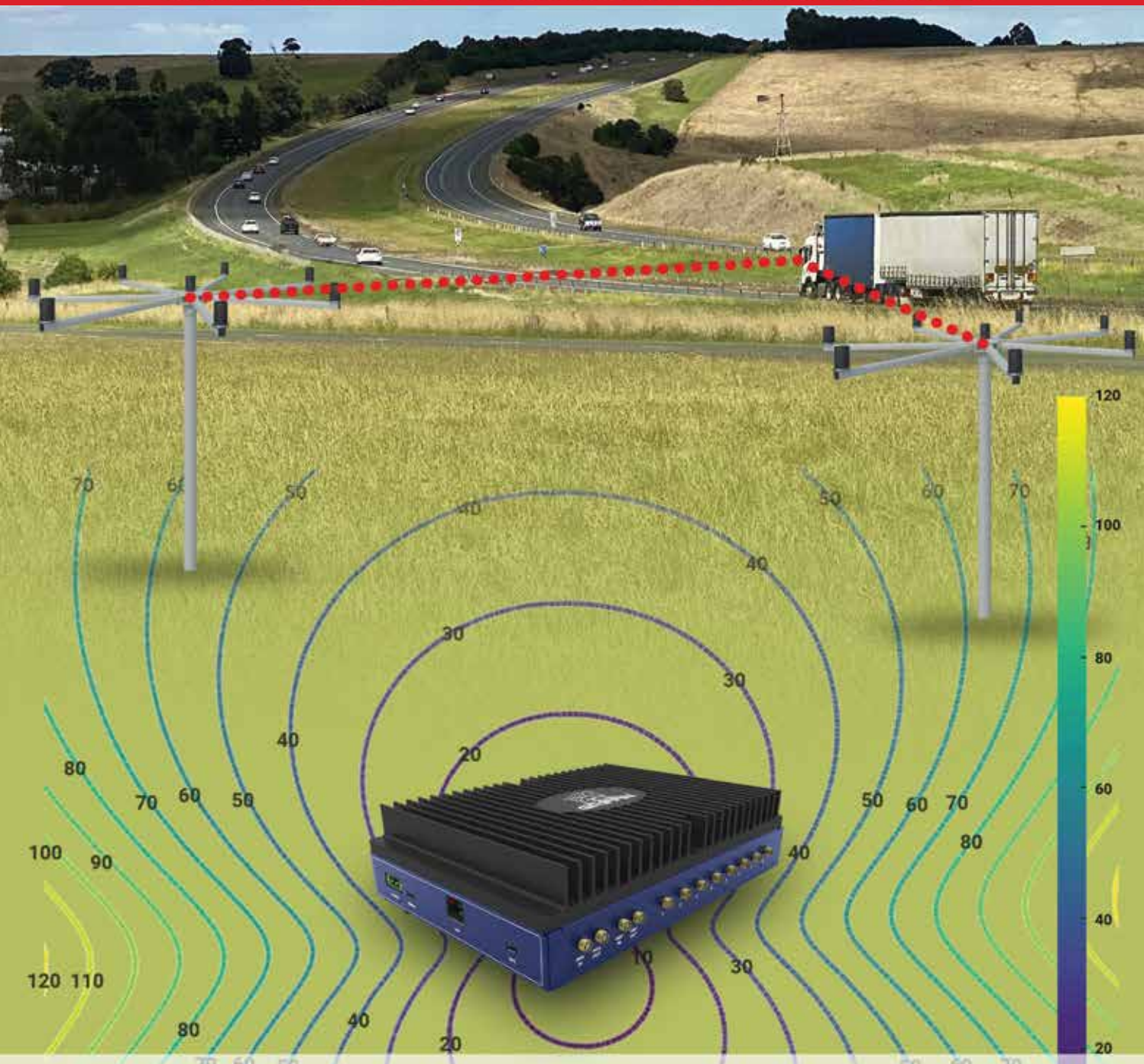

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Mapping of the Mount Everest - An awe inspiring history!

This article attempts to take a closer look at the mapping history of the Mount Everest region from its history to the present day. The survey and discovery of Everest by using classical trigonometric methods to modern-day space technology and 3D mapping is examined in this article

Khimlal Gautam
Chief Survey Officer of the Survey Department of the Government of Nepal. He was the leader of the 2019 survey of the summit of Mount Everest

Mount Everest is often considered "a symbol of something impossible". For mountaineers standing atop Everest, near the Nepal-China border on the huge ice block that caps its peak, it is a life-time dream. Before climbers scaled the world's highest mountain, several surveyors sacrificed their lives surveying and mapping in order to contribute to the worlds' understanding and knowledge of this unique and beautiful geographic icon.

Since Everest is the world's highest mountain it has been constantly studied from various aspects. This article attempts to take a closer look at the mapping history of the Mount Everest region from its history to the present day. The survey and discovery of Everest by using classical trigonometric methods to modern-day space technology and 3D mapping is examined in this article.

The icon

This iconic peak was known by various local names before it earned global fame as the highest peak. It was only after The British Great Trigonometric Survey of India determined a heigh the late 19th century that the local peoples recognized the fact that their mountain truly was the worlds' height. Europeans had prepared a rough sketch of the mountain from the northern side of Everest using their own resources before naming the mountain as the world's highest peak.

Being the highest among many of the world's highest peaks, fosters tremendous interest among geographers and the general public. Various survey authorities from across the globe began to publish the maps of Everest and its environs soon after it was recognized as the world's tallest mountain. And with the advent of the internet, and open-source data, publishers seem to be competing in publishing maps of the region for various purposes ranging from the scientific to news stories.

As awe inspiring as the mountain is, so are the maps. From the hand-drafted to digital 3D models and detailed studies of the geology and tectonic elements, these have become more readily available. But for the foundation for these maps, the rich history of the work of intrepid surveyors, mappers, geodesists, geologists, geographers, and cartographers has often gone unheralded. Do not take those maps for granted; they were borne of the skill, innovation, and bravery of many, over several centuries. There have been so many wonderful and informative maps of Everest and the region; we offer a few notable maps and their storied creation.

Early mapping in the region

Jean-Baptiste Bourguignon d'Anville (1697-1782) was an influential French geographer that is credited with greatly improving the standards for map making at the time. d'Anville is considered by some to be the first Westerner as a person to conduct a survey of Everest, in the beginning of the eighteenth century. Between 1708-1716, Jesuit missionaries led by d'Anville performed the first survey by Westerners of China. The survey included the Hindu Kush

Himalayan range and produced the Royal Map of the Chinese Empire.

In the course of this ambitious undertaking, d' Anville's team had conducted a tentative survey of the region that includes what it now is known as Mount Everest. The map printed in Beijing in 1718 covers the mountain range without determining summits of mountains. The Everest region was named Jumu Lungma (see Image 1) in Chinese language (but not specifying individual peak names). This same section of the Himalayas in northeast Nepal and south-central Tibet of China is what is now known as the Mahalangur Himalayan (Mahālangūr Himāl) range. Many of the maps of these remote and difficult to traverse regions were more like rough sketches *[Ward. M.P. Mapping Everest. Cartographic Journal 1994 Jun;31(1): 33–44]*.

Nepal's mapping records indicate that Charles Crawford, a member of the British- Kathmandu mission, was first Westerner to conduct a survey in the country. Between 1802-1803, Crawford prepared a map of the Kathmandu Valley for the first time, also determining the latitude and longitude of the valley. Further, Crawford calculated heights of mountains seen from Kathmandu, the capital city of Nepal.

As has been the case throughout history, science and mapping initiatives can be disrupted by geopolitical events. A few years after Crawford's survey of Kathmandu valley, relations between Gurkha (Nepal) and the British worsened because of Anglo-Gurkha War that lasted until 1816. Because of the war, foreigners were barred from coming to Nepal. Special permits were required to enter the Kathmandu valley until 1950, the year when the Rana Oligarchy ended.

Image 1: A part of Mountain region of D Anville Map produced in 1718. The Chinese characters inside red box read 'Jumu Lungma'.

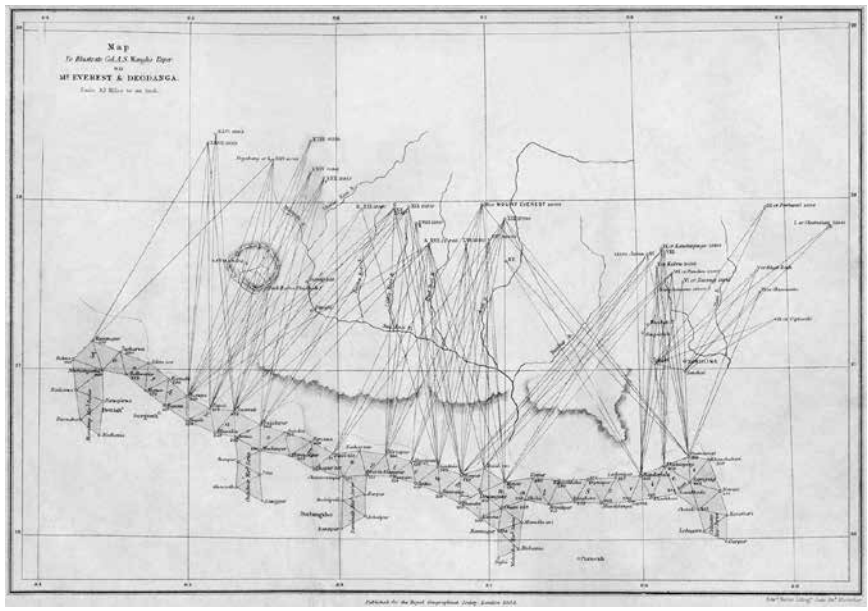

Image 2 – Waugh's triangulation map of the Himalayas, 1862 Royal Geographic Society

The Great Trigonometrical Survey

Spanning seven decades of the 19th Century, one of the most ambitious surveys in history was conducted, under the auspices of the East India Company, which sought to provide the geodetic framework to survey the entire Indian sub-continent.

Between 1847 to 1850, the Great Trigonometric Survey observed the locations and heights of some 79 mountains situated in the Hindu Kush Himalayan region. Most of those mountains are in Nepal. The survey was conducted from North Indian territories—Bihar, Patna and Lucknow—while surveyors from British-India were deployed, for triangulation surveys. They observed "Peak XV" from more than 108 miles to 118 miles far from the summit of Mt Everest. Their survey, and computations by Indian mathematician Radhanath Sikdar, proved that Peak XV was the highest peak.

The second of four successive leaders of the survey was British surveyor and geographer Colonel Sir George Everest CB FRS FRAS FRGS. The initial height of the mountain was computed from observations made during his tenure, but it was his successor who put forth Everest

Image 3 – A "Great Theodolite" of the era of the Great Trigonometric Survey. Courtesy of B. Nagarajan, Geodetic & Research Branch Museum, Survey of India

as the namesake. Naming the mountain presented difficulties as there were multiple local names for the mountain under consideration. Later Peak XV was officially renamed as MOUNT EVEREST only after a meeting of Royal Geographic Society in 1865 in London. It is said that Everest himself was not in favor of this as he felt that his name was difficult to pronounce in local languages.

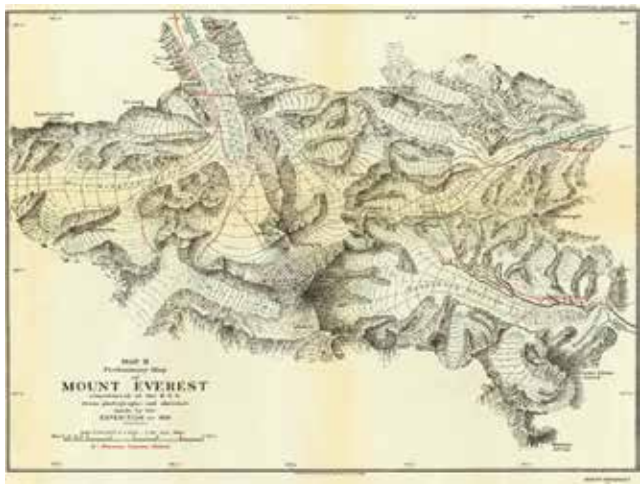

Image 4 – Preliminary Map of Mount Everest, from the 1921 expedition. C K Howard-Bury, The Reconnaissance 1921. Arnold, London, 1922.

Image 5: Partial map of Everest as seen from the northern ridge. Scale: 1 inch = 1 mile – Hans-Uri Feldman, Charles Jacot-Guillarmod 1930. Atlas of Places.

Modern age exploration

As the mountain became the focus of expeditions to reach the summit, surveyors would often accompany support teams. This year marks the centennial of the one of the first comprehensive, and arguably the most important, Everest mapping expedition of the modern age. It employed photography, and modern surveying instruments and techniques and has served as a foundation for all that followed.

The 1921 Everest Expedition took a long and arduous, four-month route in a wide arc around the region, from Darjeeling India, north to Lhasa Tibet, then southwest to the Rongbuk Monastery—at the time one of the last outposts before reaching the mountain. Major *Wheeler*, a Canadian citizen serving in British army, would later serve as Survey General of British-India from 1941-46. A Nepali surveyor working for British Survey of India- - *Lalbir Singh Thapa*, and surveyors *Gurljar Singh*, *Turbaj Singh* and a photographer *Abdul Jalil Khan* were also part of the same survey team.

There were also two British surveyors, who were also accomplished mountaineers. This combination of surveyor and mountaineer was not uncommon during the serval centuries of using triangulation for mapping—someone has to scale those high vantage points and perform the surveys. The survey team was mobilized to pursue three goals: prepare an Everest map, explore unidentified areas, and prepare a detailed map of the Everest Base Camp and surrounding areas. The team had started their survey work from the state of Sikkim in northeast India. The survey data and sketches by Major Wheeler were the basis for the famed 1921 expedition map (see Image 4) that would inform subsequent climbing expeditions, surveys, and mapping campaigns.

A young George Mallory, schoolteacher and experienced mountaineer also accompanied the expedition and assisted in the survey and logistics. Three years later, Mallory and a colleague attempted to be the first to scale Everest, only to have apparently perished near the summit. The mystery of their disappearance was not solved for over 75 years when remains were finally found, though we may never know if they made it to the top.

Aimed at assisting a 1922 Everest expedition, the Royal Geographic Society had published a map of Everest showing the route to Rongbuk Glacier in 1922. In 1925, the Royal Geographic Society prepared a map of Mount Everest based on photos and ground data captured in different seasons and over various time periods. Surveyors were successful in publishing a map of Everest on the scale of 1:63360 with a 100-meter contour interval (Image 5).

The Survey of India had first released an Everest map at a scale of 1:126720 (One inch equal to 2 miles) in 1930. The level of detail across the maps was inconsistent, so some of the places and streams in the Everest region were not named.

Image 6: Partial Everest map as released by the British-India survey department in 1930.)

Image 7: A photograph of the Everest region taken from Houston Mount Everest Expedition, 1933. News UK Archive.

Image 8: Photo of one of the two open-cockpit bi-planes approaching Everest. The Marquess of Clydesdale was chief pilot for the 1933 mission. News UK Archive.

Image 9: The new large-scale map published by the Royal Geographic Society in 1935 based on the Spender survey.

As Europeans and other foreigners were banned from entering Nepal at the time, many climbers attempted to ascend Everest from the north. The map (Image 6) shows camps set up by George Malory's team for one of his Everest expeditions.

From the Air

By the 1930's, aviation had evolved to the point where the high altitudes and harsh conditions could be overcome, and the dream of flying over Everest had been realized when two planes, a Westland PV-3 and Westland PV-6 (two-seater heavy bi-planes) landed in Pune India. Named the Houston Mount Everest Expedition, the team achieved the first successful flights over Everest on April 3, 1933.

Two aircraft had successfully, for the first time, captured both horizontal and vertical photos of Mount Everest and surrounding areas. They rounded the summit of Everest for 15 minutes, capturing hundreds of aerial photos. AR Hinks, a cartographer, and the then Secretary of Royal Geographic Society, along with then society's draftsman HF Milne processed those photos for a new Everest map.

The addition of aerial photos, and later lidar and satellite images and radar data, revolutionized mapping of the region. But even those advanced technologies required precise and accurate geodetic references, and framework.

Continuous updates

Surveyor Michael Spender was included in 1935's British expedition team led by mountaineer Eric Shipton. He was equipped with a Zeiss photo-theodolite and Wild photo-theodolite used by Royal Geographic Society, which was carried by the famous climber Tenjing Norge Sherpa. This was his first time on an Everest expedition, serving as a high-altitude worker and porter. Afterward, Spender successfully published a new large-scale map of the northern ridge of Mount Everest. Photography was performed on the scale of 1:20000 from the base of Rongbuk Glacier to the top of Everest.

Map Source: The Himalayan Journal, Records of the Himalayan Club Edited by Kenneth Mason, Vol. IX, 1937.

Survey work also featured in expeditions organized in 1936 and 1938. Noel Odell, a geologist, was also part of the expedition groups who later returned with valuable firsthand data on the geography and geology of the Everest region.

For the first time in 1945, an Everest map covering both the Nepalese and Tibetan sides was prepared. This map was prepared by compiling aerial photos taken in 1933 from Houston Mount Everest Expedition, and maps prepared by

As awe inspiring as the mountain is, so are the maps. From the hand-drafted to digital 3D models and detailed studies of the geology and tectonic elements, these have become more readily available. But for the foundation for these maps, the rich history of the work of intrepid surveyors, mappers, geodesists, geologists, geographers, and cartographers has often gone unheralded

Image 10: A map designed by Austrian cartographer Erwin Schneider in 1957 on the scale of 1:25000.

Image 11: A map designed by Swiss Cartographer Eduard Imhof having scale 1:100000.

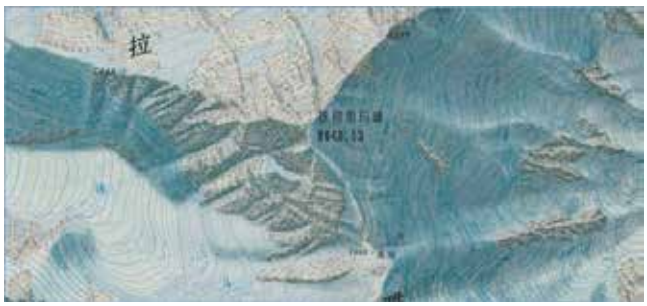

Image 12: Map of Everest region in the scale 1:50,000. Lanzhou University, China 1969 (Rev 1977).

Michael Spender in 1935 [MP Ward and P Clark; Everest 1951: Cartographic and Photographic Evidence of a New Route from Nepal; in Geographical Journal 158, 47-56, 1992].

A survey from the Nepalese frontier was performed for the first time in 1951, as part of an expedition that also included the famed climber, Eric Shipton. The survey was conducted from southern ridge *[K Mason, The Representation of Glaciated Regions on Maps of the Survey of India. Professional Paper No 25. DehraDun, 1925]*. Though an Indian surveyor named *Nath Singh* was the first to visit the Khumbu Glacier for the purposes of surveying, he was not able to complete the work due to low temperatures.

Charlie Ivan, one of the famed climbers of 1953's first ascent of Everest expedition climbed some of the mountains surrounding Everest in order to acclimatize. During these ascents, he collected valuable ground data. Based on this new data, Survey of India revised its first map published in 1930.

A year after the first successful expedition to summit Everest in 1953, a joint team comprising the Everest expedition of New Zealand and British climbers conducted a photo survey of Everest and surrounding areas. Later, in 1961, the Netherlands published another map of the Everest region by incorporating details of previous photo surveys *[E P Hillary and W G Lowe, East of Everest. Hodder & Stoughton, London, 1956]*. Between1954-55, the French Federation of the Mountain published a map of Everest and the inner Makalu region on the scale of 1:50000.

In 1957, Erwin Schneider, an Austrian cartographer, unveiled larger maps of the entire Khumbu region on the scale of 1:25000 with a 20 meter contour interval (published in English and German). After the first historic and successful Everest ascent expeditions in 1953, Survey of India calculated and published the new height of Mount Everest; 8848 meters. After releasing the new height, Survey of India released an updated, comprehensive map in 1954. This map was later downscaled to 1:50000 and was released in 1963.

In 1959, Survey of India released topographical maps encompassing all of Nepal, which was published in 274 grid sheets. These maps were compiled and prepared based on aerial

photos captured between 1956-1958, and ground surveys of the Everest region. Later, in 1960, Swiss Cartographer Eduard Imhof published a map of Everest region on the scale of 1:100000, with a widely lauded, visually attractive cartographic features. This map sold out quickly, despite a relatively high price tag for that time.

In 1961, GS Holland and GR Crone, cartographers of the Royal Geographic Society, published another map of Everest on a scale of 1:100000, showing areas of Namche Bazaar to Rongbuk Glacier in the north, Rolwaling of Dolakha in the west and Tashi Lapcha Pass in eastern region of Solukhumbu *[G S Holland and G R Crone, ' A New Map of the Mount Everest Region; in Geographical Journal 128, 54-57, 1962]*. Cartographers had collected new survey data from several locations and compiled previous data from others to prepare this map. The Royal Geographic Society in 1975 published and updated map incorporating some new data.

Likewise, a team of Chinese cartographers led by Chen Jiaming, professor at Lanzhou University, prepared an Everest map in Chinese language in 1977. Chinese surveyors had worked for 10 years on this map starting from 1966. The Royal Geographic Society of London later translated the contents of this map into English which is still being displayed at the Hall of the Royal Geographic Society.

In 1980, Bradford Washburn, director of the Boston Museum of Science, sought helicopter flight permission from Nepal's Department of Survey to prepare an Everest map on the scale of 1:10,000 with a 20 meter contour interval, aimed at avoiding mapping errors and making it useful for all in the future. The Government of Nepal granted permission through the Survey Department.

Washburn employed Nepali and Chinese Surveyors for ground verification. Using sets of aerial photographs captured by aerial survey and ground verification, an Everest map was prepared by Washburn and his team, and they published that map through the National Geographic Society (NGS) on the scale of 1:50,000 *[M P Ward, Sagarmatha-Mount Everest-Chomolungma. Map by the National Geographic Society. Review in Geographical Journal 155,433-435, 1989) and (A Keynote speech by Bradford Washburn on 15 October, 1998 in the program of the Trimble Navigation Users Conference Sunnyvale, California]*.

> Nepal's mapping records indicate that Charles Crawford, a member of the British- Kathmandu mission, was first Westerner to conduct a survey in the country. Between 1802-1803, Crawford prepared a map of the Kathmandu Valley for the first time, also determining the latitude and longitude of the valley

Image 13: Everest region map on the scale of 1:50,000 released by National Geographic Society in 1998.

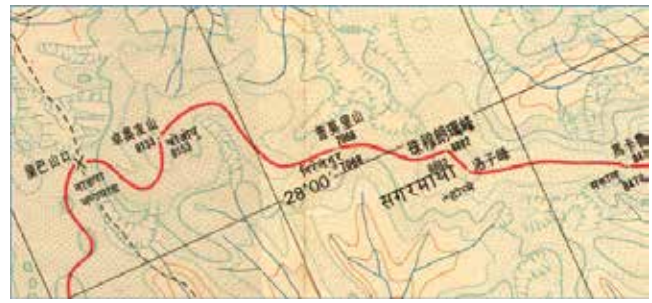

Image 14: Border map jointly published by China and Nepal in 1961.

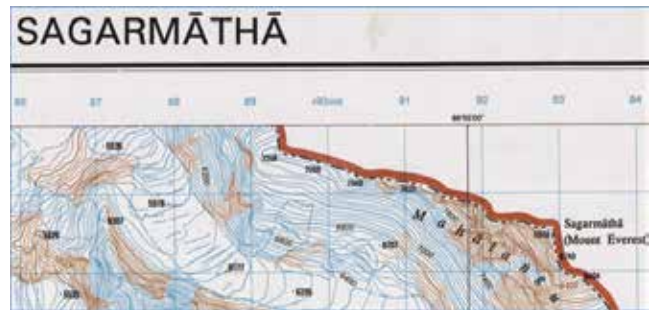

Image 15: A Base topographical map prepared by the Nepal Department of Survey.

Nepal survey department

Against tough competition among global power centers in mapping the mountains of Hindu Kush Himalayas, home to Everest, Nepal was a late comer in emphasizing the importance of surveying and mapping science, and formalizing mapping

Between 1847 to 1850, the Great Trigonometric Survey observed the locations and heights of some 79 mountains situated in the Hindu Kush Himalayan region. Most of those mountains are in Nepal. The survey was conducted from North Indian territories—Bihar, Patna and Lucknow—while surveyors from British-India were deployed, for triangulation surveys

Image 16: The author and colleagues from the Nepal Survey Department surveying the peak in May of 2019.

Image 17: 3D view from an Esri StoryMap.

Image 18 – 3D view from the Nepal side. Source: Digital Globe

activities. Gurkha armies who fought with distinction in World War I and World War II on behalf of the British Empire experienced the importance of maps. They studied maps and learned surveying skills during their deployments. The Nepal army started mapping and surveying work using plane tables in 1923 when Former Field Marshal Judda Shumsher was Shree-3 Maharaja, prior to becoming Prime Minister and Rana (ruler).

In 1957, Nepal established the Survey Department under the Nepal Army. From the very beginning of its establishment, the department focused on preparing the official cadastral maps to help regulate land tenure and land administration. In the meantime, a border marking agreement was signed between Nepal and China in 1960-61. Under the agreement, a joint map having a scale of 1:500000 was prepared. Before Nepal measured Everest, Survey of India in 1954 determined 8848 meters as its official height. But Nepal-China border map in 1961 reads Everest height is 8882 meters as measured by Sydney Burad in 1904. The reason behind mentioning the Everest height as 8882 meters in the joint map is not clear.

Since the peak of the Everest sits very close to the Nepal-China border, a strip map was prepared to show the northern and southern sides of the mountain border in the course of designing the joint-map. A separate topographical mapping unit was established later under the Department of Survey, Nepal in 1970, and at that time essential infrastructures were inaugurated to prepare topographical maps.

In 1978-79, the second Nepal-China joint border survey was conducted, and a new border map was jointly prepared on the scale of 1:50,000. In that map, the height of Mount Everest is noted as 8848.13, which was measured by the State Bureau of Surveying and Mapping of China in 1975. Nepal seems to have agreed to that.

From 1978 to 1984, the Survey Department published land resource maps of Nepal in collaboration with the Department of Forests (later to become the Department of Forests and Soil Conservation). The land resource map of the Everest region was also prepared and published.

Since 1996, aerial photographs have been taken for the preparation of base maps of the eastern part of Nepal under the Eastern Nepal Topographic Mapping Project with support of the Finnish Government. Later only in 2001, a detailed base map of the Everest region was also prepared on scale of 1: 50,000.

Presently, the Department of Survey has prepared maps on the basis of satellite images and previously created contour data.

The quest for a definitive height

There is an enduring fascination with the "height" of Everest. And indeed, a lot of mapping data has come from various expeditions for which the high-ascents were not the sole motivation, but that which gained the attention of general public.

For example, the height of the mountain was discovered incidental to a much broader mapping project. In 1852 when Radhanath Sikdar, an Indian-Bengali mathematician, rushed into the room of Sir Andrew Waugh of the Great Trigonometric Survey of India and exclaimed, "Sir, I have discovered the highest mountain of the world." Sikdar was employed as a "computer"; he had been processing observations the survey had performed with the optical instruments of the day, like Great Theodolites that weighed half a ton and had to be carried by teams of 12. Designated at the time as "Peak XV," the official height was given as 8,840 meters (29,002 feet). Everest has been measured repeatedly since, using all manner of instruments, including satellite radar. GPS was employed, for official measurement purposes, for the first time in 1999, though there is evidence that some low-precision recreational GPS units may have been carried up the mountain prior to this.

Subsequent surveys refined this to the broadly-accepted official elevation of 8,848 meters (29,029 feet), from a 1955 Indian survey, and backed-up by a 1975 Chinese survey. More recently, the multi-year Sagarmatha Height Measurement project, that performed geodetic surveys in and around mountain, included an ascent and survey of the summit. I lead the Nepal survey team especially for the survey observations on the summit in May of 2019; you can read my account of the climb and survey here.

The technology employed to take the measurements was GPS (actually called GNSS now as multiple satellite navigations systems are used) from Trimble, and ground penetrating radar (to determine the thickness of the ice on top of the peak. A second survey by a Chinese team in 2020 used similar technologies. By mutual agreement between China and Nepal the new official height of 8,848.86 meters or 29,031.69 feet (height above sea level) was announced jointly on December 8, 2020.

Digital and 3D

Theis iconic mountain continues to inspire awe; both in terms of science and the desire of many to summit. The technologies of surveying and mapping have steadily evolved, but some elements remain the same. Namely the acts bravery in collecting ground data, as the respective Nepal and Chinese surveys in 2019 and 2020 demonstrated.

Everest has now been mapped by remote sensing and direct observation in great detail, and in 3D. Cartographers, even those who have never set foot in the region, continue to create valuable and data rich maps leveraging ever increasing resources and data that are freely available online. This data has been processed into models that you can download and have a 3D printer make you scale replica. There are even virtual reality (VR) versions developed for gaming engines, where you can do a virtual ascent.

While all of this downstream lateral activity is interesting, the core data still holds fundamental value for science and management of this natural wonder and its environs. As with any lofty pursuit, practitioners are said to be standing on the shoulders of those who came before. And in the case of mapping this mighty mountain, some of those shoulders have stood higher than anywhere else on earth.

The full story of the mapping of Everest is not simply a matter of technology. Fundamentally it is the story of human connections to the mountain, the explorers, surveyors, climbers, and the keepers of oral and written tradition. Narratives may change but none can erase the history. While only known to the western world as the world's highest peak for less than two centuries, its rich history holds its own significance for all—Nepalis and people from across the globe.

Ed. This article has been published courtesy of GoGeomatics (gogeomatics.ca).

Everest has now been mapped by remote sensing and direct observation in great detail, and in 3D. Cartographers, even those who have never set foot in the region, continue to create valuable and data rich maps leveraging ever increasing resources and data that are freely available online

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Performance evaluation of the effect of QZS on precise positioning

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Japan Aerospace Exploration Agency, Japan

The contributions of QZS to precise positioning were investigated in this paper. Although we cannot solve a position using only QZS, our results showed that adding QZS to GPS was quite effective for navigation under difficult conditions. The availability of stand- alone positioning was improved, even within cluster of high-rise buildings.

Analysis of integrated navigation with GPS source variability

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GNSS/INS (Global Navigation Satellite System/Inertial Navigation System) systems have found widespread use in industry, especially in automated agriculture. Automated agriculture requires high frequency, precise, steady and smooth attitude solutions. These together with stringent cost requirements, necessitate smart integration algorithms. Given that navigation solutions can be derived from different information sources, combining several information sources can result in smoother attitude solutions relative to when a single information source is utilized. A Multiple Model Kalman Filter (MMKF) is used for this purpose. The results show that the fine attributes of both information sources, namely RTK and PDP, are adequately captured by best fix MHKF.

National GIS: Shaping India

"The success of the National GIS would be in its effective utilization for various applications"

Dr Shailesh Nayak
Chairman, National GIS Interim Core Group (IGG) and Secretary to the Government of India, Ministry of Earth Sciences

"The nation needs a GIS based decision support for governance, enterprises and citizens"

Mukund Rao
Member-Secretary, National GIS ICG while explaining the working of the ICG for the National GIS

Need for new services in land administration

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The land administration institutions had to answer the new challenges in order to fill the needs of the economy and the society for data and services. To achieve above goals the renewal, modernization of land administration institutions became essential.

Blockchain land registry best practices

The political and technical feasibility of harnessing blockchain technology to improve land administration

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Abstract

Property rights and trusted land administration are essential elements to the progress of any nation that is attempting to rise from poverty to wealth. Hernando DeSoto estimates that there exists in the world $20 trillion dollars' worth of real estate owned by the world's poor that is illiquid and ineligible to be used as collateral for loans because it is improperly titled. Blockchain, also known as distributed ledger technology, has the potential to radically change record keeping and the process of transferring title within the real estate industry. Blockchain land registries promise to increase land tenure security and transparency thereby leading to increased access to credit using land as collateral. This study catalogs political and technical obstacles to be overcome for the successful implementation of a blockchain land registry pilot. A comparative approach is employed to juxtapose pilot programs in both developed and developing nations.

Introduction

Property rights and trusted land administration are essential elements to the progress of any nation that is attempting to rise from poverty to wealth. Hernando DeSoto estimates that there exists in the world $20 trillion dollars' worth of real estate owned by the world's poor that is illiquid and ineligible to be used as collateral for loans because it is improperly titled. Blockchain, also known as distributed ledger technology, has the potential to radically change record keeping and the process of transferring title within the real estate industry. Blockchain land registries promise to increase land tenure security and transparency thereby leading to increased access to credit using land as collateral. This study catalogs political and technical obstacles to be overcome for the successful implementation of a blockchain land registry pilot. A comparative approach is employed to juxtapose pilot programs in both developed and developing nations. By combining surveys, interviews, and first-hand observation, the authors outline the major obstacles to establishing, and realizing benefits from, a blockchain land registry. After reviwing several cases and surveying professionals in the field, it emerged that political obstacles to the adoption of a blockchain land registry dwarf the technical challenges.

Blockchain technology, alternatively referred to as distributed ledger technology, is the technological framework that underpins cryptocurrencies like Bitcoin and Ethereum. The philosophical and technical mechanisms that enable a blockchain to function were unleashed on the world by way of an anonymously published white paper in 2008. The pseudonymous author, Satoshi Nakamoto, did not use the term blockchain in the paper on peer-to-peer electronic cash systems, but the clever code that enabled distributed ledger technology traces its roots to these humble beginnings. While the technology was initially utilized in the financial services industry by investors, currencies traders, and libertarian cypherpunks, a growing group of technologists and social scientists are realizing the potential applications for distributed ledger technology in solving

a variety of problems stemming from deficits in social capital. Blockchain technology has the potential to be as disruptive in the future as the internet has been over the past several decades (Casey and Vigna, 2018). As is common with disruptive technologies, most analysts and observers overestimate the technologies impact in the short-term and underestimate it in the long-term.

Blockchain technology is essentially a digital, distributed ledger that lacks a central administrator. It is a further iteration of double entry accounting developed by Luca Pacioli in the late 15th century. The technology might also be compared to the law merchants of the middle ages who acted as intermediaries in abrogating the need for trust between merchants. The opening question of Milgrom, Douglass, and Weingast's seminal paper on the role of institutions asks, "How can people promote the trust necessary for efficient exchange when individuals have short run temptations to cheat?" (Milgrom et al., 1990, p. 1). Modern blockchain technology has the capability to transform the way we think about trust institutions.

Technically speaking, a blockchain is a network of computers called nodes. These nodes use public key cryptography to ascertain the ordering and validity of transactions. When two parties transact on the chain, they use a combination of their private and public keys to submit the transaction to the nodes which then verify the validity of the transaction and add it to the chain. It is an append only data structure so once it is in the chain, it cannot be removed by anyone. If a malicious actor attempts to insert a false transaction, he or she would need to gain control over 51% of the hashing power, or nodes, of the network in a proof of work blockchain. This is nearly impossible because most chains have hundreds of nodes, each with the economic incentive to ensure that the integrity of the chain is maintained. Further explanation of this can be found, among other places, in Casey and Vigna's (2018) seminal book, *The Truth Machine*. Blockchain economics is an emerging field of interdisciplinary study that delves into the incentives, rules and governance structures of blockchains. Public Choice Theory can elucidate the ways in which blockchain economics may affect the economy (Davidson, De Filippi, and Potts 2016). While not the focus of this paper, a basic outline of blockchain economics is presented here.

As Davidson and Potts point out, the gains realized by decentralized systems in economics were first enumerated by Adam Smith when he coined the phrase dynamic efficiency. Hayek, a champion of the Austrian School, further elaborated on the benefits of open, unencumbered markets in *Law, Legislation and Liberty. Volume 1: Rules and Order* (Hayek, 1973). The Austrian school's focus on individual action and libertarian political theory meshes nicely with the economics of decentralized ledgers. The economic incentives of nodes in a blockchain network form a strong defense against malicious actors. Additionally, the decentralization of blockchain coalesces well with the Austrian's emphasis on laissez-faire treatment of markets. There are two different overarching types of blockchains; public blockchains and private blockchains. Public blockchains utilizes proof of work consensus mechanism while private chains use other consensus mechanisms like proof of elapsed time or proof of stake. The most radical and libertarian minds prefer public chains because they are nearly anonymous and are free from any centralized authority; even governments. Enterprises prefer private chains because of their hybrid approach that allows for many of the transparency and immutability benefits of a public chain coupled with the ability to selectively grant access to the network. This is important because of the regulations requiring companies to know their customer (KYC) and anti-money laundering (AML) regulations.

Public blockchain enthusiasts, while many may not know it, are most closely aligned in their thinking with the Ludwig von Mises camp of Austrian Economics. Von Mises advocated a libertarian political theory that eschewed most government regulation of the economy. This fits well with public blockchains because they are free of any centralized control and provide a good deal of anonymity to users. The enterprise blockchain advocates like IBM Corda, and Hedera fall more in line with the thinking of Hayek. Hayek, the most famous Austrian Economist, was a bit less radical in his libertarianism and relied more on empirical models than did pure Austrians. One of the reasons for his popularity, in addition to his stellar reasoning and writing, was his ability to be flexible about the need for regulation of the economy in some circumstances. Just as enterprise blockchain companies understand the need for KYC and AML, Hayek knew the business and regulatory environment in which he was operating. Most enterprises will be weary of the radical nature of public blockchains and will opt for hybrid or private chains.

Blockchain in the marketplace

Here are a few market indicators that demonstrate the rise in blockchain

Blockchain technology, alternatively referred to as distributed ledger technology, is the technological framework that underpins cryptocurrencies like Bitcoin and Ethereum. The philosophical and technical mechanisms that enable a blockchain to function were unleashed on the world by way of an anonymously published white paper in 2008

Each company involved in the development of a blockchain land registry constructs the process differently, but they generally follow a similar pattern, and most utilize private or hybrid blockchains. First, a distributed registry is established with pre-written rules coded into the smart contract. The registry has a user interface that is accessible to buyers, sellers, lenders, attorneys, appraisers, the land office, and the public

adoption across a variety of industries. Approximately 34% of executives surveyed by Deloitte say that their company has initiated a blockchain deployment and 80% of businesses see blockchain as a strategic priority (ConsenSys, 2019). The Market Cap of all cryptocurrencies increased from $18 billion in 2017 to over $200 billion today. IBM alone has 1,500 industry and technical experts working on over 500 blockchain projects, several of which pertain to land administration (IBM Blockchain, n.d.).

The true value add in blockchain is a more efficient and transparent transfer of value in a trustless environment. In other words, it does not require third party verification due to the checks and balances of the distributed network of nodes, clever code and public-private key cryptography. According to IBM, blockchain technology adds irrefutable proof that a transaction occurred because of these four qualities: consensus (agreement that a transaction has occurred), provenance (history of transactions), immutability (an append-only data structure), and finality (an agreed source of truth). In the context of land administration, one could see how these four qualities would provide gains in efficiency and effectiveness. The real estate industry is "plagued by inefficient processes and unnecessary transaction costs defended by self-interested professionals and institutions" (Baum, 2017, p. 1). While there is much to be gained in the United States with respect to efficient land markets, there is even more to be gained in developing countries. Analysts at De Soto Inc. estimate that there exists in the world $20 trillion dollars' worth of real estate owned by the world's poor that is illiquid, under producing, and ineligible to be used as collateral for loans because it is either improperly titled or not titled at all (DeSoto, 2000). The introduction of blockchain based land registries could greatly increase not only liquidity in land markets in OECD countries, but also unleash millions of acres/hectors of land to be used as collateral for loans in developing countries. Blockchain land registry pilot programs are underway in South Burlington Vermont, Chicago Illinois, Wyoming, Zambia, Rwanda, Colombia, Georgia, Sweden, and several states in India.

There are several blockchain technology companies working in the real estate, and specifically the land administration, industry vertical. The most influential include, ChromaWay, Medici Land Governance, and Propy. While there are several other blockchain real estate companies with large valuations and revenues, these three are unique in that at least part of their business model involves working with governments to streamline land administration and recording of titles. ChromaWay is a blockchain technology company that operates in multiple arenas with land administration just one of four main areas of service offerings. Medici is the leader in blockchain land governance solutions for the developing world and does some work in OECD countries as well. Propy is a more traditional real estate firm that is working to disrupt the real estate marketplace in the developed world. Their blockchain services include land administration services for the recorder's office and various other market-making services.

A blockchain solution for land administration

Prior to the description of the processes inherent in most blockchain land registries, a definition of terms is required. The most pivotal and novel phrase in this process is a smart contract. Smart contracts are "self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code. The code and the agreements contained therein exist across a distributed, decentralized blockchain network. The code controls the execution, and transactions are trackable and irreversible" (Frankenfield, 2019). The other phrase with which the reader will want to be familiar with is public-key cryptography. This describes a form of cryptography that utilizes pairs of keys, one of which is public and one of which is private. The owner of the private key is the only person with knowledge of that key but the public key can be known by anyone that would care to look. Encrypted code or text can be decrypted with a private key so that only the owner of the private key could view it. Lastly, a hash, is an algorithm that takes an input and transforms it into a smaller output. In many blockcahin applications, the SHA256 hash algorithm is employed which converts inputs into outputs of 256 bits. This translates to a string of numbers and letters that is exactly 64 characters in length.

Each company involved in the development of a blockchain land registry constructs the process differently, but they generally follow a similar pattern, and most utilize private or hybrid blockchains. First, a distributed registry is established with pre-written rules coded into the smart

contract. The registry has a user interface that is accessible to buyers, sellers, lenders, attorneys, appraisers, the land office, and the public. In each transaction, the smart contract rules grant permissions to various actors based on their role in the transaction. The public will have the fewest permissions but enough to view transaction histories and ownership. The land office and other parties with a need to see deeply into the transaction will have the broadest permissions. Buyers and sellers use a combination of public and private keys to validate their role in the transaction.

A transaction flow might follow a pattern such that the buyer and seller agree to the terms of the sale and the terms of the smart contract. Following this, appraisers and lenders conduct their due diligence and upload their findings on the blockchain registry in accordance to the procedures laid out in the smart contract. The purchaser would then submit the down payment to the smart contract escrow account.

Following this, the lender would submit the remaining payment to the same smart contract escrow account. The smart contract would then execute by sending the funds in escrow to the seller while simultaneously sending the token representing title and ownership to the buyer and changing ownership status in the registry. This process is self-actuating but is visible to and auditable by the land administration office. All of these aspects to the transactions are stored on the blockchain in hashes in order to minimize the amount of data that is stored on chain. Full copies of all information can be stored off chain with hashes and metadata that are on chain pointing back to the source documents. We can be sure that no one has changed even a comma in these documents because if something even as small as a comma or a single digit were changed, the hash would change dramatically. Figure 1 depicts the output of a title record when it is hashed with a SHA-256 algorithm. Figure 2 depicts this same title record with the addition of a single comma. As you can see, any attempt to add or change any letter or number or even spacing, on the document will generate a completely different hash.

Literature review

The literature review outlines previous studies on the connection between property rights and investment specifically around the land titling space where ownership security is increased by trusted land administration institutions. There is a diverse and expansive literature on property rights and land reforms in the realm of land administration. This paper will limit its scope to property rights involving real property and liberalizing land reforms in the area of titling and land registries. The second half of the literature tackles the literature on blockchain land registries specifically.

Property Rights are defined as control over the land itself and "return to the assets that are produced and improved" (Rodrik 2000, p. 4). Secure land rights are more broadly defined as a continuum of tenure security where the owner perceives that he or she will enjoy the benefits of ownership and there are limited chances of expropriation (Henley, 2013). In this context, expropriation is defined as confiscation of the real property or fruits of production by the state or other powerful entities. This leaves some room for more traditional and informal structures but not to the point at which the real property could be described as communal. The literature is divided into two main positions, authors who support the premise that increased property rights leads to increased investment and therefore greater societal well-being, and authors who are unconvinced of this connection. Empirical studies do not predominantly support either camp, but rather, fall between these two groups with the preponderance of the evidence falling towards a positive effect on economic growth. The majority of those that are unconvinced of the connection are not claiming that an increase in property rights has a detrimental effect, but rather, that the evidence is mixed and is obscured by a litany of confounding variables that differ from place to place and culture to culture.

In the seminal work produced by the UK Government's Overseas Development Institute (ODI), Henley (2016) identifies three frameworks for examining the causal effects of increased property rights specifically on agricultural investment. While this work finds mixed effects on the benefits of private property rights, the authors cite several prominent proponents of property rights from the development literature.

The first framework, the security effect, was originally posited by Besley and

Figure 1

Figure 2

Ghatak (2009) and states that land owners invest more in their property and reap greater rewards when they have confidence that their land will not be expropriated and that they can keep the fruits of the land. The same authors provide the second framework, the gains from trade effect, investment will increase when efficient land markets allow for land owners to maximize their comparative advantage based on whatever factor of production they have in the most abundance. This second framework is of particular relevance in this paper since the title and property registry functions normally fall under efficient land markets. The third framework, and most important for this research, is the collateralization effect put forward by Hernando De Soto. De Soto argues that land owners, who previously may have been unable to access the productive capacity of their largest asset, can use the title of their land as collateral for loans (De Soto, 2000).

In the camp of authors that are more skeptical about the positive effects of property rights, the argument goes that existing property rights systems are a product of the culture and institutions in which they are found and provide sufficient incentives for investment without the need for land reform or formalized property rights (Braselle et al., 2002 and Fenske, 2011). There is a logic to this argument, but the authors still provide evidence that land administration is significant in investment outcomes for a variety of investment types. Fenske (2011) admits that tenure is significantly linked to investment outcomes in regards to fallow plots and tree planting and only finds it insignificant as it pertains to investments in labor and fertilizer. Might it be that the labor practices are culturally engrained and may take many years to change? In this case, the land owner with capital to spare would likely choose to invest in other areas of productivity. And might limited access to fertilizer be a reason why a land owner with capital to expend would find a different avenue through which to increase his or her land's productive capacity? Brasella et al. (2002) provide a clear and convincing criticism of the aforementioned relationship between land tenure security and investment by noting that there is an endogeneity problem with the majority of studies on the topic. It is possible that greater investment leads to a greater sense of security for a variety of reasons such as establishing facts on the ground or such that the community observes the investment and is more likely to support the land owners rights thereafter. This presents the most logical argument regarding the ambiguity of the causal arrow between these variables. Brasella and her colleagues might be right, but the vast majority of academics conducting studies on this topic find a positive correlation and evidence for causation between secure land tenure and investment and make convincing arguments that the causality of this relationship begins with stronger property rights especially land tenure security. Additionally, Brasella and her colleagues only looked at one country in their study which can hardly be considered representative.

In another single country study that questions the causal arrow of property rights and development, Galiani and Schargrodsky (2010) found that property rights did lead to greater economic development, but not in the way that most authors within the literature find. They found that it was the increase in human capital that led to poverty reduction in the particular portion of the slums that enjoyed robust property rights. The authors did not do a good job parsing out the human capital variable to show that it is exogenous to other factors described previously. It does seem logical that investment in human capital would increase as the wealth of a neighborhood increases, and this would be a driver of poverty reduction. However, the authors overstep by claiming that the formalization of land and access to credit are not factors in this process. The natural experiment was not set up to effectively test access to credit or the utilization of land as collateral, and it seems likely that increased investment in human capital and increased access to credit are not mutually exclusive.

There is a group of academics that do not see private property rights as an important variable in economic growth. They range from those that think that private property rights are overrated (Trebilcock, 2008), to those that think they are harmful in some situations (Glaeser et al 2004; Fogel 2004; Schmid 2006; Leeson and Harris, 2018). Schmid (2006) argues that uncertainty around property rights can actually be a driver of growth by unshackling entrepreneurs so that they are not too constrained by reimbursing property owners if their quest for innovation becomes a bit destructive. Schmid's analysis looks at westward expansion in 19th century and finds that the lack of defined property rights created an environment for innovation. There certainly was dynamic economic growth during this period and if the lack of property rights had anything to do with it, this finding does not travel as the opening up of millions of acres of nearly undisturbed land is a one off.

The most convincing sub-strain in the literature that argues against the connection between property rights and growth is that made by Daron Acemoglu his 2005 article about institutions. He cautions that property rights can entrench the well-off at the expense of the poor by creating a rent- seeking class of property owners and a subservient class of impoverished renters (Acemoglu, 2005). While Acemoglu is a champion of property rights as can be seen in his most recent book, Why Nations Fail, he is most concerned about inclusive institutions. He would say that it is better to have private property rights than not, but we must ensure that institutions are inclusive and not merely the mechanism through which the educated and elites can concentrate more power. Advocates for private property rights should take pause here and realize that, just as free markets do not always "work," private property rights are amoral and can lead to harmful externalities in some situations.

Acemoglu's concerns about rent-seeking elites was taken to extremes in one of the more recently published articles on

property rights. Leeson and Harris (2018) do not mince words in the title of their article; Wealth Destroying Private Property Rights. They argue that the decision to privatize the commons is made by elites, and when the elites have a stake in the social wealth generated by the commons, they make good decisions about when to privatize. However, when elites do not have a stake, they may choose to privatize the commons even if that decision leads to a destruction of social wealth. The authors in this instance look mostly at African communal property and do not adequately account for issues of corruption and patronage that have coincided with many privatization schemes in Africa (Boone, 2007). With that said, they are correct that it is not entirely clear that all communal property should be privatized. There are valuable uses for the commons and institutions can be developed to administer them effectively (Ostrom, 2003).

The majority camp posits that increased access to capital, security in the asset and formalization of the asset is the mechanism that boosts the economic productivity of the asset's owner (DeSoto, 2000; Pejovich, 1990; Bethel, 1999; Hayek, 1973; Coase, 1998; North, 1973 & 1991; Rodrick, 2004; Demarest, 2009; Clague et al., 1994; Leblang, 1996; Olsen, 1993; and Rand Corporation, 2009). Others ascribe the benefits of property rights to human capital investment, government investment in social services, or other tangential benefits.

Leblang (1996) is laser focused on property rights as a driver of economic growth, but most others in this camp are equally concerned with other variables such as social norms, societal capital, geography, and history. One of the most thoughtful and oft cited scholars to engender this viewpoint is Jean-Philippe Platteau. In his book Institutions, Social Norms and Economic Development, he unpacks the variables that either support or degrade the effect of property rights on economic growth by their presence or lack thereof (Platteau, 2000). In a similar vein, Douglass North (1991) places a good deal of emphasis on institutions and the way they shape commerce and specifically, property markets. In addition to incomplete information, "transaction costs in political and economic markets make for inefficient property rights." Further highlighting the role institutions play, Ronald Coase demonstrates in "The Problem of Social Cost" that institutions play an outsized role when transaction costs are high (Coase, 1960). While North and Coase are referring to institutions more broadly, their observations include the institution of property rights. The importance of understanding transaction costs in politics and economics has proved enduring and will be revisited throughout this paper.

Likely the most well-known academic to champion property rights and, specifically, land titling programs, is Hernando DeSoto. In the opening pages of his seminal work, the Mystery of Capital, he describes the poor in developing countries by saying that "they have houses but not titles; crops but not deeds; businesses but not statutes of incorporation. It is the unavailability of these essential representations that explains why people who have adapted every other Western invention, from the paper clip to the nuclear reactor, have not been able to produce sufficient capital to make their domestic capitalism work" (DeSoto, 2000, p. 49). One would be hard pressed to find a more concise statement about the need for property rights in the developing world. DeSoto's influence and charisma has been behind most of the recent land reform in Peru and in many other countries as well. His team of researchers estimates that there is twenty trillion dollars of capital locked up in the land holdings of the poor in developing countries because there are significant issues with the titling of their land (DeSoto, 2000). If they were able to gain access to a reliable titling system for their land, they could use this asset in the formal economy to generate wealth.

In developed countries, the idea of property rights is so engrained in our social and legal fabric, that people are not quite sure what a world without those rights would look like. In fact, they likely have not thought to imagine such a world (DeSoto, 2000; World Bank, 2010). At this point, the institution of property rights, especially as those rights relate to land, has taken on a heuristic quality in that there is no need to think critically about something so logical. This is not to say that there are not those in the West who argue for more communal property and less private property, but rather, that the knowledge about how the current institution of private property developed has been lost to our collective memory. Private property and sound land governance is one factor that has enabled Western countries to develop economically at such a blistering pace (DeSoto, 2000; Pejovich, 1990; Bethel, 1999; Hayek, 1973; Coase, 1998; North, 1973; Leblang, 1996). China's meteoric rise presents a challenge to this theory at first glance. However, there are a few reasons why, after further inspection, China is less problematic. China abolished private property early on and in the cities in 1982, but then quickly changed tack and in 1994, allowed for 70-year leases of residential property and slightly shorter leases on commercial property (Clark, 2017). It remains to be seen what will happen as some of the leases begin to expire, but it is almost as if this is a face-saving measure as the Communist Party admits that private ownership and cultivation of property is essential to growth. It was in the 1990s and 2000s that China's growth really took off with GDP growth averaging around ten percent per year for several years.

The institutional quality of land governance and the surrounding rights is of paramount importance. The empirical studies described above show that cadaster and land administration systems cannot be copied and pasted from the developed world onto the developing world because of the unique social and historical traditions in each country and the lack of institutional memory for such a system. The legal institution of property rights that supports an efficient land market does not fit into the "more formal and indigenous rights to land found especially in developing countries where tenures are predominantly social rather than legal" (World Bank, 2010).

Another difference between developed land administration systems and developing ones stems from transaction costs. Elucidated by the great Ronald Coase (1960), transaction costs can include market research, enforcement of property rights, and bargaining costs. An enlightening study conducted by Harvard academics in an impoverished area of Peru elucidated one of the nuanced aspects of land tenure reform. The study found that government titling drives did not necessarily increase access to credit when the funds are sought from a private lender but it did for public lenders (Field and Torero, 2006). However, they did find that homeowners with titles are 10% more likely to "have undertaken housing improvements in the last two years prior to the survey" and that "titled households are 15% more likely to finance improvements through formal loans" (Field and Torero, 2006). The land title availability did increase access to credit from public lending institutions, but for access to capital to make a demonstrable effect on a community, private lending must also be part of the equation. The main reason the authors gave for this lack of private lending was that of transaction costs. The cost of collateral processing, confirmation of title, foreclosure, and resale are immense relative to the small size of the loans requested by many of the urban poor. This issue of transaction costs is not one that should be quickly overlooked as it can be a major driver in "credit rationing" in developing countries (Coase, 1960; Field and Torero, 2006). The authors tackle another interesting challenge by teasing out the effects on demand for credit from the effects on supply of credit. We agree that it is an interesting academic inquiry to understand the nuance between the effects of property titling on supply and demand of credit, but it is even more interesting and relevant to get at how the process of increasing access to credit can be improved through technological advances in land titling.

The World Bank Report on Land Administration and Governance provides several examples, mostly from the developing world, in which corruption in land administration and governance have derailed development. For example, they note that in places like Kenya, India, Tanzania, Ethiopia and Bangladesh, to name but a few, corruption within land administration and governance is a major obstacle to economic growth (World Bank, 2010). In Honduras, around 80% of land held by private individuals is either untitled or incorrectly titled (Collindres et al., 2016). To make matters worse, a 2015 audit of the Honduran land titling entity uncovered more than 700 irregularities, most of which were related to "criminal acts of corruption" (Collindres et al., 2016). The system is highly politicized in that elected officials change titles for key supporters or refuse to enforce the titles of political opponents. In India, it is estimated that 66% of all civil cases in the court systems involve disputes over land (Thomason Reuters Foundation, 2016). Millions of these cases are currently awaiting adjudication in the backlogged Indian court system. It is estimated that the lack of land rights in India is a greater cause of poverty than illiteracy and the caste system (Kanojia, 2015).

As one might expect with such a novel concept, there are but a few strains in the blockchain based land registry literature. The first group to write on the subject were technologists and academics with some level of tech enthusiasm who foresee myriad applications for blockchain technology in the social sciences (Casey & Vigna 2018; Collindres et al. 2016; Scott, 2016; and Snall 2017). There is another strain in the literature that can be described as the "not yet" group (Vos 2017; and Lemieux 2016). These authors recognize the potential of blockchain in land administration but feel that the technology is not mature enough to replace legacy systems of land registration. The last strain in the literature are those that feel blockchain technology is not the right fit for land administration (Barbieri and Gassen, 2017). The following arguments posited by the various subgroups in the literature were on display at the 2017 and 2019 World Bank Conference on Land and Poverty in Washington, D.C.

The enthusiasts argue that blockchain technology in land registries has the potential to open up the credit market for those who would normally not have access (Scott, 2016), curb corruption (Collindres et al., 2016), and minimize transaction costs (Casey and Vigna, 2018). These are all theoretically feasible but are not without obstacles. To dwell on the obstacle, though, is to miss the potential upsides of a successful implementation of a blockchain based land registry. The economic vitality and productivity of the world's poor are severely hampered by informal property arrangements and their inability to access credit markets (DeSoto, 2000). A blockchain based land registry that made records transparent to all citizens could reduce transaction costs and establish a function market for immovable property. USAID did a study in Uganda in which they found that the land of those who were secure in the property rights was 63% more productive than those who had a fear of eviction (USAID, 2016). No doubt there is room to critique how they measured the increase in productivity, but it is telling that organizations like USAID and the World Bank have been some of the first to champion innovation in the property registry space.

As described previously, the second strain in the literature represents a group that is more cautious than optimistic about the prospect of using blockchain as a tool in land administration. They observe that there are many avenues through which to implement a blockchain based system, and many questions that must be answered prior to an implementation. In the technical realm, these academics and practitioners debate whether or not the land registry should be placed on a public platform like Bitcoin or a private platform like the one that the Austin-based startup Factom attempted in Honduras. A public blockchain platform would provide "proof of work" checks that enhance immutability of the blockchain, but the transaction costs are high. Public blockchain transactions require 5,000 times more energy than a Visa credit card transaction (Barbieri and Gassen, 2017). This would appear not to be a problem since there might only

The blockchain registry might just contain digital signatures and proof of ownership while the centralized database could contain files that are normally found in cadasters like land use plans, deeds, GIS overlays, regulations issued by the courts and any other overlays needed to complete the picture. This is not as preferable to all of the documents being kept on the blockchain as corrupt officials could change the parcel sizes by altering GIS images or swapping them out for new ones

be a few hundred real estate transaction per day in a given country, but with electricity and energy costs high in developing countries, this is a dissuasive factor. Put another way, a blockchain network that process 300,000 transactions per day would require a similar amount of energy that is consumed in a small country in that same twenty-four-hour period (Vos, 2017). The process that is so time and energy intensive is the "proof of work" process. While proof of work enhances the security and immutability of the system, it requires complicated mathematical computations along with majority consensus algorithms that require a good bit of computing power.

In 2017, when Vos presented his paper at the World Bank Conference on Land and Poverty, the only alternative was a tradeoff between system security and massive amounts of computing power. If one wanted to design a system that required less computing power and therefore less energy, one could utilize a private blockchain or use a different type of consensus mechanism, but this arrangement would provide less system security. A new startup company based in Richardson called Hedera has raised over $120 million dollars as they work to build a "governing council" of a public hashgraph network that would act as a trust layer that sits on top of the internet (Baird et al., 2018). This kind of innovation is exactly what we might expect in a sector as dynamic as blockchain technology. Hedera provides a solution to the energy consumption issue described above by allowing secure transactions at over 500,000 transactions per second (Baird et al., 2018). The author met with Mance Harmon, CEO of Hedera, this fall and he (Mance) is confident that their platform can solve the majority of the issues.

The third strain in the literature consists of academics and practitioners who feel that blockchain applied to land administration is not the right fit. Barbieri and Gassen (2017) are the most critical of the arrangement proposed by blockchain enthusiasts. While they recognize the economic hindrance caused by the face that "of the 7.3 billion people in the world, only two billion have title that is legal and effective," they are fairly skeptical that blockchain will be the avenue through which these property owners formalize their property holdings (Barbieri and Gassen, 2017). Their primary concern is that a public blockchain network is not secure enough from cyber-attacks, and a private blockchain network, while more secure, forgoes many of the benefits inherent with a distributed ledger that make blockchain attractive in the first place.

Other issues raised by the authors include; seismic shifts in political power, the risk of lost cryptographic keys, re-encryption challenges, energy consumption, and data accumulation issues. These are all valid concerns, but the concerns are no more or less, just different, than the concerns with the current systems in place in many developing countries. The authors are from Germany and therefore are likely thinking of the challenges in reference to the well-oiled machine that is German property rights law. With this as the backdrop, it would be logical to give more weight to obstacles because the cost benefit analysis falls short when thinking about a stable OECD country with centuries of property law under its belt. However, when considered in the context of less developed countries, the risks and rewards begin to make more sense. First of all, their concern about seismic political shifts is irrelevant because no cadastre or land management system, blockchain included, can protect against a totalitarian takeover or the predations of a roving bandit to use Mancur Olson's terminology. If the state is captured by a despot, he can just as easily confiscate the real property of his people whether the property records are listed in a centralized database, on paper, or on a blockchain based ledger.

I question the logic of their concerns about lost cryptographic keys as well. Might it not be equally possible that the government entity responsible for land administration could misplace, damage, or corrupt a file that holds land registry information? At least in the blockchain scenario, the person who has the most interest in the property, the owner, is the one responsible for keeping their cryptographic key in a safe place rather than a bureaucrat with no dog in the fight. Furthermore, it is not as if someone who misplaces their cryptographic key will immediately be evicted from their land. On the contrary, no one else will have the key either and hence there is no way for a false claimant to enter the picture. In a situation where there is not proof of ownership under the current centralized storage system, a false claimant could hire an unscrupulous lawyer to draft a

forged document and a legal battle over ownership would ensure (under the best of conditions, under the worst, there would be bloodshed). In the same situation under a blockchain based land registry, a false claimant would have no way to claim ownership since they would not be able to produce the cryptographic key.

The scenario described above heightens the need for strong network security to ensure that keys are not stolen in a hacking attack. This concern has the most merit out of all of their concerns. If 51% of blockchain miners and nodes reach consensus about some data point, then that data is secured into the blockchain as truth (Nakamoto, 2009). Therefore, if one group can amass 51% of the miners and nodes to initiate some nefarious transaction, then the system has been compromised. While it is extremely unlikely that one group could do this since it is in the interest of the other blockchain miners and nodes to maintain a truthful ledger, it is possible. This kind of attack can be prevented on a private blockchain and it has become impossible on a blockchain such as the one that Hedera has developed. The Hedera platform retains the benefits of a public blockchain but has the security of a private blockchain since it is overseen by a distributed council of respected intermediaries. The best analogy I can think of for this is that it is like the difference between direct democracy and the representative sort. Direct democracy is like a normal public blockchain in that it is prone to populism and demagoguery, while representative democracy retains many of the benefits of direct democracy but with more stability.

The last issue that will be addressed from the literature in the "never blockchain" camp is the argument that data accumulation makes blockchain too cumbersome to be used in land registries. It is true that blockchains steadily accumulate data since all of the data must remain as a whole rather than transmission of the limited, pertinent data in a transaction (Barbieri and Gassen, 2017). However, Bitcoin is continuing to operate with a quarter of a million transactions per day at time of writing. The author must be forgiven for thinking that property transactions would take place at a rate of a few hundred per day or, at the most, a few thousand per day in a given country. Another way to ease this problem is to maintain a blockchain based land registry alongside the original centralized land registry database.

The blockchain registry might just contain digital signatures and proof of ownership while the centralized database could contain files that are normally found in cadasters like land use plans, deeds, GIS overlays, regulations issued by the courts and any other overlays needed to complete the picture. This is not as preferable to all of the documents being kept on the blockchain as corrupt officials could change the parcel sizes by altering GIS images or swapping them out for new ones. In order to realize the full effect, all documents must be transferred to the blockchain. Rather than utilize a public blockchain that could suffer from a data accumulation problem, the best solution lies in utilizing a quasi-public blockchain like Hedera. Hedera operates with 100% efficiency in that no block is pruned of the proverbial vine like it is in Bitcoins blockchain. This greatly increased efficiency makes data accumulation a nonfactor since the process of amalgamating blocks requires much less computing power. The main point is that innovate companies are already finding ways to overcome data accumulation challenges, and these solutions will only become more effective in the future.

The case of Texas

The administration of property in the United States, and Texas specifically, is a nuanced affair lacking in uniformity and cohesion. Municipal America is a fragmented puzzle linking over 90,000 local jurisdictions providing the most basic services to American citizens. Texas alone is home to 254 counties plus local jurisdictions of both general and limited authority. The classic fragmented approach leaves each county with the responsibility of administering land. While most counties have a limited budget to embrace land administration innovation, the large number of land administration offices creates opportunities for decentralized experimentation.

Why must Texas municipal leaders pursue land administration innovation and cooperation in the first place? Their world is changing at a rapid pace as Thomas Friedman argues in his book, *Thank You for Being Late*. Individuals and organizations typically avoid adapting unless change is on the horizon. Municipal America is experiencing trends and challenges that mandate innovation especially in real estate and land administration.

The nature of Texas politics and its governing history challenges government

Table 1

Question	Score out of 5
Do you see value in harnessing blockchain technology for the recording of real property information?	4.8 / 5
To what degree do you agree with this statement? The county/municipal government will be the greatest barrier to the adoption of a blockchain land registry. (1 being you do not agree and 5 that you agree fully)	3.3/5
To what degree do you agree with this statement? The title companies will be the greatest barrier to the adoption of a blockchain land registry.	3.8/5
To what degree do you agree with this statement? The public sector bureaucracy will be the greatest barrier to the adoption of a blockchain land registry.	2.8/5
To what degree do you agree with this statement? The banks and lending institutions will be the greatest barrier to the adoption of a blockchain land registry.	2.0/5
To what degree do you agree with this statement? The land administration office will be the greatest barrier to the adoption of a blockchain land registry.	4.0/5

The major concern surrounding blockchain based land registries has been the technical challenges presented by first generation blockchain technology. There were serious concerns about transaction speed, on chain storage capacity, and accessibility in the developing world. With each passing year, these challenges continue to evaporate with modifications and improvements in blockchain technology

innovation. The state embraces a hybrid of the traditionalist/individualistic political cultures. Most Texans are skeptical of government and public spending at all levels but this may actually favor innovation in the land administration space rather than dissuade from it. Regional cooperation offers one way for counties to keep costs low and benefit from economies of scale in regards to the implementation of a blockchain registry. Counties in larger cities have more incentives to innovate in this way due to higher volumes of real estate transactions and reliance on property tax revenue. In the Dallas/Ft.Worth area, the third largest metropolitan area in the United States, two counties have expressed a willingness to consider a blockchain land registry. The authors conducted meetings with Ellis County elected officials and members of their land administration office to explore a blockchain land registry pilot program in partnership with a blockchain real estate company. While we will keep the name of this company confidential, they offered to conduct the pilot program at no cost and provide the backend technology support to make this project happen. Several weeks into the discussion, political forces derailed the pilot project. It is unclear which level of county government stepped in to end the project, but it appears that someone in authority became aware of the pilot and put an end to it. There have been several other failed pilot projects in the United States, and of course a few successful ones (see Medici and Propy), but from conversations with country officials and blockchain firm representatives, it seems that political factors more often derail pilot projects rather than technical challenges.

Blockchain technology is progressing rapidly and technical barriers to implementing a blockchain registry a falling quickly, but political barriers persist. An informal survey of blockchain land administration officials and country representatives in Texas shed light on this phenomenon.

From this unrepresentative survey, we can see that respondents believed that the land administration offices and title companies would be most resistant to a blockchain land registry. Anecdotal experiences from the authors align with the respondents. This analysis, though, does not travel. There are numerous land administration jurisdictions around the world. While patterns will emerge, each pilot program and implementation will have unique political challenges.

The case of Honduras

The World Bank conducted a comprehensive study titled the Land Administration and Information Systems group. The failed blockchain land registry pilot program in Honduras is further evidence that the political challenges extend across the world. Factom, a respected blockchain company out of Austin, Texas, won a contract to develop a tamper-proof blockchain land title system. Amidst some controversy, Factom CEO Peter Kirby admitted that the project had stalled for "political reasons" (Kirby, 2015). The project was to begin in the city of La Ceiba and expand after the proof-of-concept had been established (Rizzo, 2015). The Honduran Government remained silent about the project throughout. The authors spoke with members of the Factom team about the "political reasons" behind the stall in the project but nothing was ascertained other than the fact that it was clear that friction within the government was at the root. As mentioned in the literature review, around 80% of land held by private individuals in Honduras is either untitled or incorrectly titled (Collindres et al., 2016). To make matters worse, a 2015 audit of the Honduran land titling entity uncovered more than 700 irregularities, most of which were related to "criminal acts of corruption" (Collindres et al., 2016). The system is highly politicized in that elected officials change titles for key supporters or refuse to enforce the titles of political opponents. It is not hard to imagine why this kind of project would create friction amongst the elite in the country. Recognizing the state of the Honduran land registry, the World Bank itself conducted research and initiated a land registry improvement project in Honduras in 2018 with their Land Administration and Information Systems project (Gonzales, 2018). Given the prior experience of World Bank project managers, they are likely to be much more adept at navigating the political hurdles in Honduras than the Factom project managers. Certainly, Factom provides excellent products and services, but perhaps a partnership with the World Bank or other NGO within Honduras would have provided a smoother entry into the world of land management politics.

Conclusion and discussion

In years past, the major concern surrounding blockchain based land registries has been the technical challenges presented by first generation blockchain technology. There were serious concerns

about transaction speed, on chain storage capacity, and accessibility in the developing world. With each passing year, these challenges continue to evaporate with modifications and improvements in blockchain technology. However, the underappreciated obstacles to the successful implementation of a blockchain land registry are of a political nature. Control over land administration processes, real estate transaction processes, and generally control over accurate information provide incumbent, rent-seeking firms with lucrative profit opportunities. This paper has argued that the largest obstacle to the adoption of blockchain technology for land administration is undoubtedly in the political sphere.

As can be seen by several failed pilot programs and the informal survey conducted as part of this paper, political obstacles appear to be more of a deterrent than the technical obstacles with the technology. There remain limitations to blockchain technology for the land recorder's office, but the pace of advancement in this technology demonstrate that these limitations can be overcome by private firms that realize the revenue potential for the company that can sell software applications for the purpose of improving land governance. The good news is that academic are more familiar with analyzing the kinds of principal-agent problems and veto players that characterize the political obstacles to adoption.

Future research must focus on stakeholders, veto players, and mapping economic incentives. If veto players should be given incentives to transition to a more transparent system, then perhaps they can be turned into advocates rather than obstacles. Examples of this may look like title companies running a node on the blockchain network with the ability to more efficiently track the chain of title. While a blockchain land registry negates the need for title insurance in the long run (once enough transactions and reliable data have been logged on the blockchain), in the short and medium term, they can benefit from lower labor costs due to increased transparency and efficiency.

While political obstacles may be more difficult to overcome than the technical, it is important that we understand the main barrier to the adoption of blockchain land registries for the sake of the future flourishing of the jurisdictions that wish to employ them.

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How one million people in India's Odisha slums gain land rights

The Tata Trusts began the effort with pilot studies that gained momentum with the historic passage of the Odisha Land Rights to Slum Dwellers Act in August 2017

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In India, having patta or property title, forms the basis for social and financial opportunity. It often provides the only acceptable proof of address required to access government benefits, enroll children in school, and open a bank account. An ambitious program in India's state of Odisha has begun to deliver land rights to people living in slums.

"This project was conceived from the realization that slum dwellers are the lifeline of the city and our state can't be developed without uplifting them," said G. Mathi Vathanan, commissioner-cum-secretary, Housing and Urban Development Department, Government of Odisha.

The Tata Trusts began the effort with pilot studies that gained momentum with the historic passage of the Odisha Land Rights to Slum Dwellers Act in August 2017. The legislation puts a program in motion to identify, map, and issue title for parcels of land in 2,000 slums that house a population of 1 million people.

"This landmark legislation is going to change the face of slums across the country," said R. Venkataramanan, managing trustee, the Tata Trusts. "Hopefully, this effort in the slums of Odisha will have a ripple effect across the country with a positive social and economic impact."

"This is an incredibly exciting program," said Frank Pichel, chief programs officer at Cadasta Foundation, a nonprofit that provides technical tools and services to support the efficient documentation of land rights globally. "This first-of-its-kind program has shown the potential of bottom-up data documentation leading to formal certificates of occupancy in urban informal communities."

The legislation promises a Certificate of Occupancy of 30 square meters (roughly 320 square feet) free of cost to the economically disadvantaged, as well as financial assistance of up to 200,000 rupees ($2,900) that the homeowner can use to create a permanent dwelling. Odisha's effort is part of Prime Minister Narendra Modi's larger Housing for All Mission that aims to build 20 million urban housing units and 30 million rural homes by 2022.

Local data collectors use a combination of handheld apps and paper forms

To date, more than 24,000 certificates have been distributed to slum dwellers and an additional 50,000 will be delivered by the end of March 2019

to record data from occupants. (Photo courtesy of Cadasta.)

Getting the record right

Around the world, 70 percent of the population live on land without holding title. Peruvian economist Hernando de Soto helped raise awareness about the impact of granting land title by writing several best-selling books. He argues that guaranteeing urban property rights is a precondition for alleviating poverty.

Many governments have experimented with de Soto's ideas and the World Bank has loaned funds to support related projects, however, the complexities of land reform have yielded several false starts.

According to Transparency International, the land sector is the third most corrupt government sector globally behind police and judiciary.

"A lot of places where we've worked, the slums are owned by the politically or economically powerful," Pichel said. "They are happy for it to remain informal, because they can control it and continue charging unreasonable rents knowing they can always evict a person if they don't pay."

Even where land records exist, historical information can be inaccurate or not up-to-date. Often, when reforming land records, it's cheaper and easier to inventory existing occupancy rather than correct old records.

"In other countries we've seen deed books with blank or torn out pages," Pichel said. "A torn-out page means someone's deed disappeared. A blank page means the official can predate a deed to give favor to the person that pays them the most."

Streamlined digital workflows have started to reverse these issues.

"Technology brings in ease of doing this accurately, transparency in the process, removes discrepancies, reduces the dependency on human interventions, and brings in speed in execution," Vathanan said. "It also helped avoid large-scale disputes, litigation, and discontentment that would have resulted in frustration and failure."

Paper maps of drone-captured imagery provide a top-down view to guide discussions among neighbors. (Photo courtesy of Cadasta.)

Efficient workflows

The government's partner, the Tata Trusts, brought in global best practices by mobilizing partners like Norman Foster Foundation, Omidyar Network, and Cadasta. The government also partnered with more than 27 local civil society organizations for data collection and validation.

They started data collection by using drones to capture high-resolution imagery of the slum areas. This imagery formed a backdrop within the geographic information system (GIS) for drawing boundaries and assigning a plot number. Next, data collectors went door to door using a mobile application to collect survey information from each household.

"We brought in state-of-the-art technology and expertise to complete the task in the most efficient manner," said Shishir Ranjan Dash, who leads the project for the Tata Trusts.

Each step of the way, the teams relied on Esri technology, tailored by Cadasta for the purpose of capturing land information. Workflows include handheld applications configured for the survey task, a claim review process, steps to transfer the formalized land records to the government, and the delivery of four formal certificates of occupancy to the occupants.

Using GIS apps, the field teams, made up of one field manager and five data collectors per neighborhood, achieved a steady pace of capturing records for 200-250 households per day. This fast pace is important given the extent of the task. The data collectors are local slum dwellers, who capitalize on their local knowledge to

Local data collectors use a combination of handheld apps and paper forms to record data from occupants. (Photo courtesy of Cadasta.)

Paper maps of drone-captured imagery provide a top-down view to guide discussions among neighbors. (Photo courtesy of Cadasta.)

speed the work and ensure its legitimacy.

Smartphones are central to the process. Field crews use phones for all steps and the popular texting application WhatsApp is used to communicate progress.

"The number of people in emerging economies interacting with GIS via a web browser on their smartphone as opposed to a computer is incredibly high," Pichel said. "A few years ago, I would get incredibly frustrated by bandwidth constraints, but that's no longer the case."

"This program was deliberately designed for doorstep delivery of services," Vathanan said. "We are pleased that land certificates have been distributed without requiring the slum dwellers to visit any government office even once."

To date, more than 24,000 certificates have been distributed to slum dwellers and an additional 50,000 will be delivered by the end of March 2019.

The community gathers around a computer to review land records that were captured. (Photo courtesy of Cadasta.)

Occupants sign a form to certify their ownership, which results in a certificate of occupancy. (Photo courtesy of Cadasta.)

Studies show that land title helps lift residents out of poverty by erasing the fear of eviction and cultivating safety and dignity. Title to a house turns it into an insurance and savings tool to provide security for owners during old age or bad times

The community gathers around a computer to review land records that were captured. (Photo courtesy of Cadasta.)

Compounding benefits

In other countries that have implemented land title reform in informal settlements, long-term stability has evaded residents. From Cambodia to the Democratic Republic of the Congo, giving land title in slums close to commercial centers has resulted in quick land sales and a total turnover of people, with the original settlers displaced within a year's time.

"In the case of Odisha, the property documentation that residents get enables the properties to be inheritable, but non-transferable," Pichel said. "So, they can't sell it, but they could leave it to heirs, and it's mortgageable."

Studies show that land title helps lift residents out of poverty by erasing the fear of eviction and cultivating safety and dignity. Title to a house turns it into an insurance and savings tool to provide security for owners during old age or bad times.

Occupants sign a form to certify their ownership, which results in a certificate of occupancy. (Photo courtesy of Cadasta.)

"What you often find in slums where there is a risk of eviction is that somebody remains in the house at all times," Pichel said. "That way, they can move out all the possessions quickly. With someone needing to be there, it means a child's not going to school or an adult isn't out earning an income."

Land title also shifts investments into more permanent structures. Instead of spending money to rebuild every year after monsoon storms hit, the resources can be placed into more permanent structures that withstand wind and rain. "It is important to create a sense of ownership among the people," said Shikha Srivastava, the Urban Habitat Portfolio lead at the Tata Trusts. "To ensure this, we are upgrading the slums through a participatory decision making process where the community shares their development vision."

The State of Odisha's investment in slums includes roads, drainage, fresh water supply, toilets and sewers, street lights, common work sheds, parks and playgrounds. This expanded vision of the program goes beyond the original promise of land title and includes the transformation of slums into livable habitat.

The article first appeared at https://www.esri.com/about/newsroom/blog/how-one-million-people-in-indias-odisha-slums-gain-land-rights.

Xylariam partnership with Cardinal Geospatial

Xylariam has added Cardinal Geospatial to their robust network of partners. Cardinal Geospatial provides clients the ability to analyze past events, streamline current operations, and guide decision-making about the future. They provide custom solutions for a variety of spatially-enabled industries including UAS, utilities, and the natural resources sector. Xylariam boasts robust development teams, a combination of onshore and offshore individuals, who have worked together for decades. *www.xylariam.com*

Geo-data platform by Fugro

Fugro has completed the first phase of a 2-year contract with Atlantic Shores Offshore Wind (Atlantic Shores) to build and manage a centralized, cloudhosted Geo-data repository for the company's lease development off the coast of New Jersey in the US. The web-based engagement platform was recently delivered and utilizes Fugro's Gaia technology to provide Atlantic Shores and their stakeholders with a single source of updated Geo-data and documentation. To develop the Geo-data repository, Fugro is integrating public datasets and historical project data with realtime field data, including information from Fugro's ongoing metocean, geophysical, geotechnical and environmental programmes. *www.fugro.com*

RMSI partnership with Enzen UK to support SGN

RMSI has been awarded with a GIS application support and maintenance project for Scotia Gas Network (SGN). The engagement is in partnership with Enzen, as part of which RMSI will manage the Esri-based GIS Application requirements for SGN for a period of 5 years. RMSI will be providing support and maintenance services to SGN for Esri 10.x based applications; GIS Core 10.1.1, GIS PRM & GIS Web 10.1.1 classified as core front-office applications. The project is managed by RMSI professionals providing L2 and L3 support to SGN users on these GIS applications. *www.rmsi.com*

Boston University uses Bluesky aerial photomaps

Researchers at Boston University are using high resolution aerial photography to investigate how important coastal ecosystems are responding to climate change. The study focused on an area of salt marsh in Massachusetts which saw an extreme storm event deposit more than 15 years' worth of sediment onto the marshes. Using high resolution aerial photography from Bluesky researchers were able to examine the deposits in detail recording measurements of deposit's distribution and total cover. A second survey of the site has recently been completed by Bluesky to map depressions in the marsh surface, called potholes, which are important indicators of how the salt marsh is responding to rising sea level. *www.bluesky-world.us*

Intermap wins contract under OTA from NGA

Intermap Technologies has announced an OT award from the National Geospatial-Intelligence Agency (NGA) to produce continually updated (low latency) foundation data for high-priority national security areas of interest. This award marks Intermap's return as an NGA contractor for the first time in nine years. Intermap will help NGA change the way foundation data is created, managed and disseminated. *www.intermap.com*

Bentley Systems' Seequent acquisition of Aarhus GeoSoftware

Bentley Systems recently announced that its Seequent business unit has acquiredDanish companyAarhusGeoSoftware, a developer of geophysical software. Aarhus GeoSoftware,a spinoff company from Aarhus Universityin Denmark, develops the software packages AGS Workbench, SPIA, Res2DInv, and Res3DInv for the processing, inversion, and visualization of geophysical data from ground-based and airborne electromagnetic (EM), electrical resistivity tomography (ERT) remote sensing, and other sources.

GPS III SV05 control transferred to 2 SOPS

The US Space Force's Space and Missile Systems Center (SMC) transferred Satellite Control Authority of the GPS III SV05 to the 2nd Space Operations Squadron at Schriever (2 SOPS) Air Force Base on June 28. Nicknamed Armstrong, the fifth GPS III satellite was launched into space on June 17. GPS III SV05 received operational acceptance approval on June 29, making it the first GPS III SV to receive SCA handover and operational acceptance within 24 hours and decreasing the time from launch to on-orbit operational capability by a staggering 97%.

In 2020, the GPS enterprise launched two GPS III SVs in the midst of a global pandemic. According to Los Angeles Air Force Base, home of SMC, the delivery time from launch to operational acceptance approval has continued to shrink, with innovation and teamwork across the GPS enterprise enhancing rapid identification and elimination of redundant on-orbit verification steps. Launch of SV05 was the first National Security Space Launch on a previously flown Falcon 9 booster, reusing the same booster that delivered GPS III SV04 to orbit in November 2020.

GPS III SV05 joins a constellation of 31 operational satellites. *www.spaceforce.mil*

M9HCT-A-SMA Multi-band GNSS antenna by Maxtena

Maxtena, Inc, introduced the world's most advanced, smallest, patented GNSS antenna for high precision and autonomous multi-frequency applications. The M9HCT-A-SMA antenna is a high accuracy, multi-frequency active helix GNSS antenna + L-band corrections services. It will offer simultaneous GNSS reception on L1: GPS, GLONASS, Galileo, Beidou, L2: GPS L2C, Galileo E5B and GLONASS L3OC and L5: GPS + L-band corrections in a rugged, compact and ultra-lightweight form factor. *https://maxtena.com*

NHAI makes drone survey mandatory for all national highways projects

In order to enhance transparency, uniformity and leverage latest technology, the National Highways Authority of India (NHAI), under Ministry of Road Transport & Highways has made mandatory use of drones for monthly video recording of National Highway projects during all stages of development, construction, operation and maintenance.

Contractors and Concessionaires shall carry out the drone video recording in presence of Team Leader of the Supervision Consultant and upload comparative project videos of the current and last month on NHAI's portal 'Data Lake', capturing various project related developments during the month. Supervision Consultants shall analyse these videos and will provide their comments on the digital monthly progress reports covering various aspects of the project development.

Additionally, Project Directors of NHAI shall undertake monthly drone survey from the date of signing of contract agreement till start of construction of the project at site and also on completion of the project. NHAI will also undertake monthly drone survey in all developed projects where NHAI is responsible for operation and maintenance.

Apart from this, mandatory deployment of Network Survey Vehicle (NSV) to carry out road condition survey on the National Highways to enhance quality will enhance the overall quality of the highways as NSV uses latest survey techniques such as high-resolution digital camera for 360 degree imagery, Laser Road Profilometer and other latest technology for measurement of distress in road surface. *www.pib.gov.in*

Walmart invests in DroneUp

In our ongoing effort to get customers the items they want, and fast, we know it will take a well-coordinated network of delivery solutions that span the streets, sidewalks and skies. Some of these solutions are still emerging, but they're already showing encouraging results.

Last year, we partnered with DroneUp, a nationwide drone services provider, to launch trial deliveries of at-home COVID-19 self-collection kits. The trial demonstrated we could offer customers delivery in minutes versus hours. Now, after safely completing hundreds of drone deliveries from Walmart stores, we're making an investment in DroneUp to continue our work toward developing a scalable last-mile delivery solution.

DroneUp operates an on-demand drone delivery network that matches their database of more than 10,000 Federal Aviation Administration (FAA) certified pilots to missions nationwide.

Conducting drone deliveries at scale is within reach. DroneUp's expertise, combined with our retail footprint and proven history of logistics innovation, puts us right where we want to be for that day. Because when it comes to the future of drone delivery, we know the sky's the limit.
- By John Furner, CEO and President, Walmart U.S.
https://corporate.walmart.com

Parrot unveils ANAFI Ai

Parrot, a leading European drone group has announced ANAFI Ai: a drone that sets new standards and capabilities for professionals.

ANAFI Ai is the first drone to use 4G as the main data link between the drone and the operator, which is a game changer for the drone industry. Users will no longer experience transmission limitations thanks to ANAFI Ai's 4G connectivity, which enables precise control at any distance. For Beyond Visual Line of Sight flights, it stays connected even behind obstacles.

For the first time, ANAFI Ai embeds a Secure Element in the drone and in its Skycontroller 4. The 4G link between the drone and the user's phone is encrypted.

The Secure Element protects both the integrity of the software and the privacy of data transferred. ANAFI Ai's uniquely designed obstacle-avoidance (OA) system detects obstacles in all directions, using stereo cameras to sense objects and automatically avoid them. *www.parrot.com*

Axon and DroneSense partnership

Axon, the software platform for drones in public safety, has announced a strategic partnership to provide public safety agencies with an end-to-end drone software solution, including piloting, administration, evidence management and live streaming.

Axon will implement DroneSense's piloting, program management and operations solution via Axon's unmanned aircraft program, Axon Air. DroneSense will also integrate its offering with Axon's digital evidence management platform, Axon Evidence, and real-time operations hub, Axon Respond, to provide agencies with a comprehensive solution to start and operate a drone program. This integration will streamline first responder and drone pilot communications. *www.axon.com*

senseFly Introduces eBee TAC Fixed-wing UAS

senseFly have launched of eBee TAC, an advanced fixed-wing Unmanned Aircraft System (UAS) optimized for covert tactical mapping operations in defense, security and governmental sectors. The eBee TAC offers active field personnel access to accurate and reliable location data and maps, delivering the field intelligence and situational awareness needed to act with confidence and precision across rapidly-changing environments. At just 1.6 kg (3.5 lbs), eBee TAC is a lightweight, ultra-portable and robust solution specially designed for tactical mapping and analysis in defense applications and is currently employed by U.S. forces. *www.senseFly.com*

Teledyne Optech launches CZMIL SuperNova

Teledyne Optech and Teledyne CARIS have announced their next generation bathymetric lidar, the CZMIL SuperNova. It boasts the best depth performance and the highest green laser point density in its class. Introducing SmartSpacing technology for even and efficient point spacing, real-time processing capability for reduced post-processing time and configurable modes for maximizing performance in different water environments, the SuperNova provides a wide range of inputs for climate change modelling and is Ideal for inland water environments, base mapping for coastal zones and shoreline. *www.teledyneoptech.com*

LDROBOT announces launch of LD-AIR LiDAR

LDROBOT has announced the launch of LD-AIR LiDAR, a ready-to-use compliant laser sensor with 360-degree sensing capabilities. This affordable LiDAR component makes any robot smarter and is available now on Kickstarter. The ability to recognize objects and the environment is a key feature of many robots. LiDAR enables robots to scan their surroundings, make highly accurate maps, and navigate freely. Using advanced technology, LD-AIR LiDAR is a high-accuracy TOF sensor with a 360-degree scanning range that is able to sense the surrounding environment by taking up to 4,500 laser ranging samples per second to actualize obstacle detection and autonomously map any area. *ldrobot.com*

Satellite-based maritime surveillance services for the UK Royal Navy

The UK Royal Navy has awarded a 12 month contract extension to Airbus covering the continued provision of satellite-based maritime surveillance services for the Joint Maritime Security Centre (JMSC). The contract follows the successful completion of a proof of concept phase, and will ensure the continued monitoring of areas of interest in UK waters and ultimately protect UK sovereign borders from suspicious vessel activity. Using optical and radar imaging as well as AIS (Automatic Identification System) data, Airbus will provide reports about vessels within the UK Exclusive Economic Zone, as well as information that will help in the prevention of potential illegal activities.

JMSC, which is the UK government's center of excellence for maritime security, required a series of services that would provide intelligence to augment their own surveillance activities. Under the agreement, JMSC will benefit from a large range of Airbus' surveillance and analytics capabilities. *www.airbus.com*

Microsoft becomes a founding member of Space ISAC

The Space Information Sharing and Analysis Center (ISAC) has announced Microsoft Corporation has become the Space ISAC's newest founding member. The Space ISAC is the only space-dedicated ISAC with a mission to facilitate collaboration across the global space industry to enhance the nation's ability to prepare for and respond to vulnerabilities, incidents, and threats; to disseminate timely and actionable information among member firms; and to serve as the primary communications channel for the sector with respect to this information. This mission is made possible through the investment by initial founders which also serve as board members. *https://s-isac.org*

Orbital Sidekick announces upcoming launch of Aurora

Orbital Sidekick (OSK) has announced the upcoming launch of its newest and most powerful hyperspectral imaging satellite: "Aurora." It leverages OSK's previous experience collecting and analyzing hyperspectral data to provide action-oriented insights on the world around us, with a core focus on sustainability. The Aurora satellite will serve OSK's customers in the energy, mining, and defense sectors, including expanding contracts and pilot program opportunities for oil and gas pipeline monitoring & methane mapping, clean energy resource exploration, sustainable mining practices, and wildfire risk mitigation.

The Orbital Sidekick Aurora Satellite is a 30-kilogram precursor to the six 100-kilogram ESPA class GHOSt satellites scheduled for launch in 2022. Seattle-based launch services provider Spaceflight will be coordinating the launch with a total of 36 payloads onboard the SpaceX Transporter-2 rideshare mission, taking place June 25, 2021 at Cape Canaveral Air Force Base in Florida. *orbitalsidekick.com*

India launches LiDAR survey reports to augment water in forest areas

Union Environment Minister Prakash Javadekar, Government of India has released LiDAR-based reports mapping out the water requirement within forest areas in 10 states. These reports will be used to augment groundwater in forest areas so that animals don't venture out in search of water, Javadekar said.

The LiDAR (light detection and ranging) technology was used to create 3-D images of the project areas to recommend soil and water conservation structures. The surveys were carried out at forest areas in Assam, Bihar, Chhatisgarh, Goa, Jharkhand, Madhya Pradesh, Maharashtra, Manipur, Nagaland, and Tripura.

The project was awarded to WAPCOS, a PSU under the Jal Shakti Ministry, is a first of its kind and a unique experiment using LiDAR technology which will help augment water and fodder in jungles areas thereby reducing human-animal conflict. With the participation of State Forest Departments, WAPCOS identified one major ridge inside a forest block in these states with average area of 10,000 ha selected in each State for preparation of Detailed Project Reports for planning and identifying locations and structures for construction of appropriate and feasible micro soil and water conservation structures consistent with site specific geography, topography and soil characteristics. *https://indianexpress.com*

UP42 teams with HEAD Aerospace

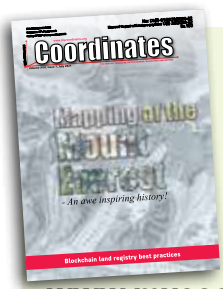
UP42 has signed an agreement with HEAD Aerospace of Beijing to make image data from more than 40 innovative Chinese Earth Observation satellites available on the UP42 marketplace. The broad selection of imaging capabilities from the constellations dramatically expands the range of applications in multiple sectors, with the most significant benefits expected in Infrastructure, Transportation, Utilities, Agriculture, Government.

The UP42 marketplace currently contains more than 50 geospatial data sets, including satellite imagery from six international organizations. The newly added satellites' diverse and often unique imaging capabilities include wide-swath imaging at very high resolution, nighttime acquisitions, frequent intraday revisits, tri-stereo collection, and hyperspectral imaging. HEAD Aerospace is the international distributor of satellite imagery collected by commercial Earth Observation missions. *https://up42.com*

FARO acquires HoloBuilder Inc.

FARO® Technologies, Inc. has announced the acquisition of HoloBuilder, Inc.

HoloBuilder brings to FARO its leading photogrammetry-based 3D platform, which delivers hardware agnostic image capture, registration and viewing to the fast-growing Digital Twin market. With an initial focus on Construction Management, HoloBuilder's technology platform provides general contractors a solution to efficiently capture and virtually manage construction progress using off-the-shelf 360° cameras. *www.faro.com*



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IoT technology powers drones to deliver critical medical assets

KORE, a leader in Internet of Things ("IoT") solutions and worldwide Connectivity-as-a-Service ("CaaS"), showcased the innovative enablement of IoT connectivity that is making it possible for Australian drone-powered logistics company Swoop Aero to transport COVID-19 vaccines into isolated areas of the world at Mobile World Congress Barcelona.

Swoop Aero's air logistics solution enables the reliable transport of medical commodities, including early pathology samples, diagnosis kits, antiretroviral therapy medication and vitamins across Malawi, the Democratic Republic of Congo, Mozambique as well as Australia, the United Kingdom and the Pacific. *korewireless.com*

HERE, Vodafone and Porsche partnership

In the future, new technologies will be a key enabler to make unclear traffic situations safer. HERE Technologies, Vodafone and Porsche are working together to achieve this objective as part of a feasibility study. The aim of the study is to improve road safety with the help of 5G technology and highly precise, real-time identification and localization of hazardous traffic situations.

HERE Technologies, Porsche and Vodafone are trialling how 5G technology and highly precise location determination can improve traffic safety and reduce the number of road accidents in the future. The three companies are collaborating in the development of a real-time warning system so that vehicles and their drivers can receive hazard warnings directly, without any delay, and therefore be responded to immediately. At the Vodafone 5G Mobility Lab in Aldenhoven, the partners are testing the real-time warning system under conditions, similar to everyday situations, for the first time.

Above all, the focus is on hazardous situations that are not visible or difficult to see for vehicle drivers, such as when the view is blocked by the traffic ahead. Captured by camera and sensor systems, using artificial intelligence and precisely localized with high-definition map and positioning technology, the data determined will be processed and evaluated directly on the roadside and on the edge of the network through Multi-access Edge Computing (MEC). In the form of dedicated alerts using 5G mobile network technology and an intelligent MQTT message broker, the data can then be transmitted without delay to road users travelling towards the hazard.

To detect dangerous situations ahead, the Live Sense SDK from HERE Technologies is used alongside HD maps and positioning technology. Integrated into consumer devices with front-facing cameras, this system uses computer vision and artificial intelligence to identify objects and changes in the behaviour of other road users or road conditions that could lead to hazardous situations. Based on this information, Live Sense SDK generates real-time hazard warnings for drivers. *https://newsroom.porsche.com*

Salesforce Maps integrates Smarter AI Dashcams

Smarter AI has announced an agreement with Salesforce Maps to integrate Smarter AI Dashcams to increase efficiency and regulatory compliance for enterprise vehicle fleets. Regulations, including the US SAFE Act 2021 and EU Regulation 2019/2144, and the growth in e-commerce are bringing more technology into commercial vehicle fleets. A recent report by ABI Research stated that AI video telematics, driven by these factors, is projected to grow 29% annually until reaching $8 billion in 2026.

Smarter AI Dashcams enable programmable AI, including distracted driving, forward collision, and lane departure warnings, and are supported by the AI Store™, Smarter AI's growing ecosystem of AI models and developers. Salesforce Maps is a location-based intelligence tool, built for global enterprise-level teams, designed to optimize sales processes and territory management. *https://smarterai.camera*

TomTom's Advanced Mapping Technology

TomTom have announced that drivers of the all-new Nissan Qashqai in Europe will benefit from TomTom's advanced mapping technology and connected services. Its cutting-edge maps will support the new Nissan Qashqai's upgraded ProPILOT with Navi-link driver assistance, as well as the NissanConnect infotainment system's built-in navigation. It will provide the new Qashqai's NissanConnect infotainment system with an innovative over-the-air map update solution. *www.tomtom.com*

Rohde & Schwarz and Quectel cooperation

Rohde & Schwarz in partnership with Quectel announces the verification of selected 3GPP test cases based on a system with its R&S CMW500 wideband radio communication tester against a Quectel AG15 C-V2X module.

Cellular-V2X (C-V2X) is a key technology, which will improve road safety and accelerate autonomous driving in the coming years. Specifically, the C-V2X PC5 interface, operating in the 5.9 GHz frequency enables direct, reliable, low latency communication between vehicles (V2V), vehicles and infrastructure (V2I) and vehicles and pedestrians (V2P). In order for the automotive industry to deploy this technology in a timely manner, cooperation between suppliers in this industry becomes increasingly important. *https://www.pressebox.de*

Verizon acquires Senion

Verizon has acquired precise positioning company Senion, and with it, the company's indoor positioning platform, which uses machine-learning sensors to deliver sub-meter accuracy for precise positioning and navigation of indoor spaces. The acquisition expands the Verizon's location-based technology offerings and will provide customers with capabilities like indoor wayfinding, geofencing, location sharing and analytics and predictive intelligence.

ASO Inc. takes delivery of RIEGL VQ-1560 II-S LiDAR system

Airborne Snow Observatories, Inc. has just taken delivery of one of the first in North America cutting-edge RIEGL VQ-1560 II-S airborne laser scanners, just as the ASO program at NASA pioneered the use of the first of RIEGL's dual laser scanner, the LMS-Q1560 in 2013. This new LiDAR system, with its doubled laser power and high pulse frequency, will allow ASO Inc. to far more efficiently achieve its needs to uniquely measure snow water equivalent across extensive mountain basins.

ASO Inc. is a public benefit corporation that was created via technology transfer from the NASA Jet Propulsion Laboratory to continue and expand ASO operational snow mapping and runoff forecasting to the world's mountains. Through coupling of RIEGL LIDAR, imaging spectrometer data, and physical modeling, ASO Inc. maps mountain snow depth, snow water equivalent, and snow albedo. This is accomplished with unrivaled accuracy and coverage, enabling reliably high accuracy streamflow forecasting for water management agencies, irrigation districts, and municipalities. *www.riegl.com*

Robotic-based solutions from Topcon

Topcon Positioning Group has announced system solutions designed to support curb and gutter paving professionals by maintaining productivity and accuracy, even when facing difficult GPS coverage issues. Using either the GT-1200 series robotic total station or the LN-150 robotic layout navigator, customers can augment their existing Millimeter GPS concrete paving solution and remedy issues such as foliage canopies, large buildings, tunnels, overpasses, and more.

Both instruments offer support for a prism solution to quickly switch between Millimeter GPS and LPS (local positioning systems); both use Topcon LongLink communication for robust connectivity. The self-leveling LN-150 is ideal as an easy-to-use, cost-effective robotic solution while the GT-1200 series instruments can serve that purpose and perform a full range of functions as a standalone surveying total station. *www.topconpositioning.com*

Trimble X7 and Perspective 3D Scanning Solution garners three international design awards

Trimble has announced that the Trimble X7 and Perspective 3D Scanning Solution has received following three international design awards:

- iF Design Award 2021
- Red Dot Design Award 2021
- New York Design Award 2020

The Trimble X7 was designed and developed by an accomplished international project team with decades of experience using and designing scanners, total stations and application software. The team included Trimble employees in product management and marketing in Westminster, Colorado; project management in Danderyd, Sweden; optical instrument design and manufacturing engineers in Jena, Germany; scanning hardware, firmware and software engineers in Paris, France; and application engineers worldwide.

ART-KON-TOR Produktentwicklung GmbH of Jena, Germany was primarily responsible for the X7's industrial design for usability, function, ergonomics and housing construction. *www.trimble.com*

M-Code Military GPS user equipment to Germany by BAE Systems

BAE Systems, Inc. received the first contract from the Space and Missile Systems Center's Space Production Corps to deliver M-Code GPS User Equipment to Germany. Under a Foreign Military Sales contract, it will deliver advanced M-Code GPS technology to Germany.

The German FMS order focuses on BAE Systems' Miniature PLGR Engine – M-Code (MPE™-M), the smallest, highest-performance M-Code GPS receiver for ground applications available today. MPE-M delivers precise positioning, navigation, and

timing capabilities; anti-jamming and anti-spoofing capabilities; a modern security architecture; and a size suitable for space-constrained applications. *www.baesystems.com*

Juniper Systems introduce its latest Cedar rugged tablet

Juniper Systems have launched its latest Cedar rugged tablet — the Cedar CT8X2. It offers increased processing power, RAM, and storage, all running on the Android™ 10 operating system. The CT8X2 offers all this while retaining the same powerful GNSS functionality of the previous generation at the same affordable price point. Powered by an octa-core Snapdragon CPU from Qualcomm, the CT8X2 provides a snappy user experience while running demanding applications. *https://junipersys.com*

Ultra-low latency of five milliseconds by Orolia's GNSS simulators

Orolia has recently announced the launch of its Real-Time Performance capability which achieves an ultra-low latency of five milliseconds. The feature will be standard on all Skydel-powered GNSS simulators. Skydel is the software-defined simulation engine that powers Orolia's advanced GNSS simulators including its BroadSim (available via Orolia Defense & Security) and GSG product lines.

Skydel's software-defined architecture, offering unparalleled flexibility and adaptability, is designed to meet the most demanding GNSS simulation testing requirements in the automotive, military, space and other high-tech industries. Skydel also supports Hardware-in-the-Loop (HIL) simulations without sacrificing ultra-low latency and high-end performance. *www.orolia.com*

Hexagon announces Luciad 2021

Hexagon's Safety, Infrastructure & Geospatial division announced the release of Luciad 2021, a significant update to its platform for building advanced location intelligence and real-time, situational awareness applications. It delivers enhanced performance, improved development capabilities and more dynamic web applications.

With Luciad 2021, defense, aviation, maritime and other organizations can develop more effective and reliable web applications. It also features enhancements to the SDKs for desktop and on-board vehicle applications. LuciadLightspeed can now seamlessly integrate into JavaFX-based applications. This makes it easier to embed LuciadLightspeed map components into user interfaces and introduces new capabilities, such as high-resolution map printing. *www.hexagongeospatial.com*

GMV develops a new maritime Galileo receiver

Under the Advanced Shipborne Galileo Receiver Double Frequency (ASGARD) project GMV is collaborating with the defence and security company Saab, to develop a new civil, legislation-compliant, Galileo-signal-using maritime receiver.

Co-funded by EUSPA (former GSA), ASGARD aims to boost Galileo take up in maritime transport by developing shipborne e-GNSS (European GNSS) data-processing receivers. Ships operating under the International Convention for the Safety of Life at Sea (SOLAS) have to be fitted with a maritime GNSS receiver compliant to the international standards of the International Maritime Organization (IMO).

The new maritime receiver represents a new generation of GMV's Galileo receivers and will be integrated into a Saab navigation system in a format that is already well known by the maritime industry. The receiver will be tested according to the requirements of the European Maritime Equipment Directive for GNSS receivers. *www.gmv.com*

Septentrio announces partnership with XenomatiX

Septentrio and XenomatiX are starting a partnership enabling high-quality Lidar solutions.

XenomatiX will be using the compact and robust GNSS/INS receiver from Septentrio, AsteRx SBi3 Pro+, to provide millimeter accurate analysis of pavement conditions using global positioning coordinates. Septentrio's high-quality GNSS/INS will be a part of Xenomatix' Road LiDAR called XenoTrack, which has been the solution of choice for road surveyors and road management companies. *www.septentrio.com*

ULTRAHACK Drone precision tournament 2021

Launched in July, this international innovation tournament will assemble in late October, when the finals are organized in connection with the massive Assembly Summer '21 Fall Edition- event in Helsinki. The key objective of the tournament is to solve essential challenges regarding the utilization of drones, a.k.a. unmanned aerial minicopters. These challenges are especially related to equipment landing and precision flight in various demanding and changing environments. The contestants have an unprecedentedly wide spectrum of navigation- and sensor technology to utilize.

The competition consists of several challenges. Responsible for the execution of each challenge is Ultrahack and Robots Expert Finland, who are promoting the

use of unmanned aerial vehicles. In addition, the competition has a wide range of partners who offer their technology for the benefit of the competitors.

Stara, the establishment of the city of Helsinki, offers a challenge for the competitors to solve, where the aim is to execute an urgent delivery in a simulated manner, by using Stara's own system and subcontracting chain. The challenge includes all the steps between ordering and successfully delivering a product by drone to a construction site in an urban environment. *www.ultrahack.org*

Developing the "brains" behind Astroscale's debris removal spacecraft

Developing the "brains" behind Astroscale's debris removal spacecraft Astroscale UK has been working in partnership with RUAG Space to develop the "brains", based on RUAG Space's constellation On Board Computer (cOBC), to command Astroscale's space debris removing ELSA-M Servicer spacecraft.

For these kinds of innovative missions, a high performing "brain" (On Board Computer) is needed. The computer from RUAG Space will include a Global Navigation Satellite System (GNSS) receiver and interface unit, all in one box. Once in orbit the computer controls the ELSA-M spacecraft, enabling repeated multi-debris removal manoeuvers and management of equipment, reaction wheels and magnetometers linked to it. *www.ruag.com*

Rx Networks announces StarCourse

Rx Networks™ GNSS assistance service Location.io™ adds StarCourse™, the next evolution of extended ephemeris services. Real-time ephemeris services have long-provided GNSS chipsets in connected mobile devices a head-start in determining position accurately and quickly. For devices with limited connectivity, typical extended ephemeris solutions have provided a head-start with 7-14 days of ephemeris data.

With the evolution of IoT, low power consumption and a limiting of connection time are essential for extending the usable life of the device. This creates a challenge for IoT vendors seeking an extended ephemeris offering which can minimise onboard resource usage without compromising on accuracy. StarCourse exceeds this challenge with a 50% reduction in RAM requirements, 90% reduction in CPU cycles, and ephemeris accuracy exceeding that of previous market offerings. *www.rxnetworks.com*

NavVis announces the launch of NavVis VLX

NavVis has announced the launch of NavVis VLX 2nd generation, a new iteration of the flagship mobile mapping system optimized for scanning both indoor and outdoor environments. NavVis VLX 2nd generation will enable more professionals in the surveying and architecture, engineering & construction (AEC) industries to complete a wider variety of reality capture projects with high speed and precision. *www.navvis.com*

Management of "Terrestrial Time" and "Live-Sky Time" sources

Microchip Technology Inc. has integrated its BlueSky GNSS Firewall with its TimePictra 11 synchronization monitoring and management platform to protect 5G networks and other critical timing infrastructure from GPS signal jamming and spoofing while providing single-console visibility across the entire timing architecture.

In addition to requiring precise timing from GNSS sources, critical infrastructure operators need accurate timing to be distributed across their networks so they can ensure reliable performance and service delivery. TimePictra provides full control and monitoring for resilient timing architectures created with Microchip's broad product portfolio including its TimeProvider 4100 grandmasters for 5G network synchronization. *www.microchip.com*

Products to protect critical infrastructure

GPS Patron Provides products and services to protect equipment, especially critical infrastructure that depends on GNSS. Its GP-Probe TGE2 is designed to protect your time server from threats such as spoofing, jamming, ionospheric scintillation, and system errors. The built-in PPS phase error measurement feature ensures that you can monitor the status of your time server by measuring the time offset between the internal PPS and the external PPS. *https://gpspatron.com*

HawkEye 360 Formation-Flying microsatellites

HawkEye 360 Inc. successfully launched its Cluster 3 radio frequency geolocation microsatellites built by Space Flight Laboratory (SFL). Carried aboard the June 30 SpaceX Transporter 2 mission, the Cluster 3 formation-flying microsatellites join in orbit the HawkEye 360 Cluster 2 and Cluster 1 Pathfinder satellites – all built by SFL.

The HawkEye 360 Constellation detects and geolocates RF signals for maritime situational awareness, emergency response, national security, and spectrum analysis applications. Cluster 3 significantly expands HawkEye 360's global revisit and collection capacity, stated the Herndon, Va., company. *www.utias-sfl.net*

New rate sensors for small satellites by Honeywell

Honeywell has unveiled a new rate sensor specifically intended to help small satellites navigate increasingly crowded orbits above the Earth's surface. The new micro-electromechanical system (MEMS)-based product will provide lower cost and power consumption in a smaller size, all while maintaining high levels of performance. At only 145 grams, Honeywell's HG4934 Space Rate Sensor is roughly the same size and weight as a golf ball. *aerospace.honeywell.com*

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Mapping Venice Beach during the Pandemic

SimActive announced the use of its Correlator3D product by GEO1 to produce colorized point cloud data of Venice Beach, CA. The project took place during the COVID-19 pandemic in the hope of capturing a pedestrian free dataset along the strand, which is typically populated with tourists and locals alike. *www.simactive.com*

Pix4D partnership with Beijing Skymap

Pix4D have announced the signing of an exclusive reseller partnership with Beijing Skymap Technology Co., Ltd. in mainland China. With the diversification of Pix4D's product portfolio to meet the specific needs of industries like surveying & mapping, inspection, construction, agriculture, and public safety, it was natural to partner with an experienced company such as Beijing Skymap Technology Co., Ltd.

Two New Arrow Series GNSS Receivers: The Plus Models by Eos Positioning

Eos Positioning Systems (Eos) have released two new Arrow Series GNSS receiver models: the Arrow Gold+™ and Arrow 100+™.

The Arrow Gold+™ includes all the features of the standard Arrow Gold GNSS receiver model. However, the plus model includes several enhanced features:

- 3.5 hours longer battery life for a total of 11 hours of field autonomy
- Support for additional GNSS signals including concurrent use of BeiDou B3 and GPS L5 signals when using RTK corrections
- Support for the upcoming Galileo E6 High-Accuracy Service (HAS)

The Arrow 100+™ includes all the features of the standard Arrow 100 GNSS receiver model. However, the plus model includes several enhanced features:

- 6 hours longer battery life for a total of 18 hours of field autonomy
- Support for Atlas H50 (Basic) service subscriptions

Both Arrow Gold+™ and Arrow 100+™ have built-in capabilities of the Eos Bridge™ to connect with external sensors. Also, both have the ability to connect multiple mobile devices to a single Arrow GNSS receiver via Bluetooth (sometimes called "multipoint")

MARK YOUR CALENDAR

September 2021

Commercial UAV Expo Americas
7-9, September
Las Vegas USA
www.expouav.com

ION GNSS+ 2021
20-224 September
St. Louis, Missouri, USA
www.ion.org/gnss/index.cfm

Mapping The Future Of Land Administration & CSDILA's 20 Years Celebration Event
20-23 September, 2021
Melbourne, Australia
https://www.csdila20-fig.org

November 2021

Digital Construction Week
24-25, November
London, UK
www.digitalconstructionweek.com

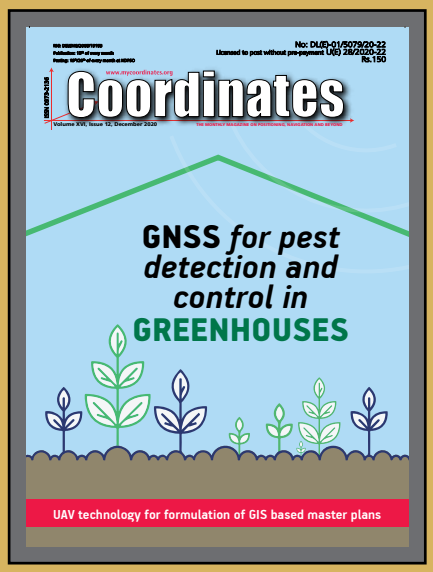
Navigation 2021
15-18 November
https://rin.org.uk

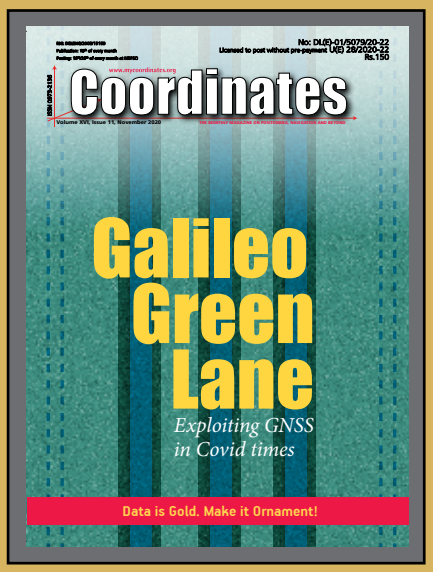
GEO Business
24-25 November
London, UK
www.geobusinessshow.com

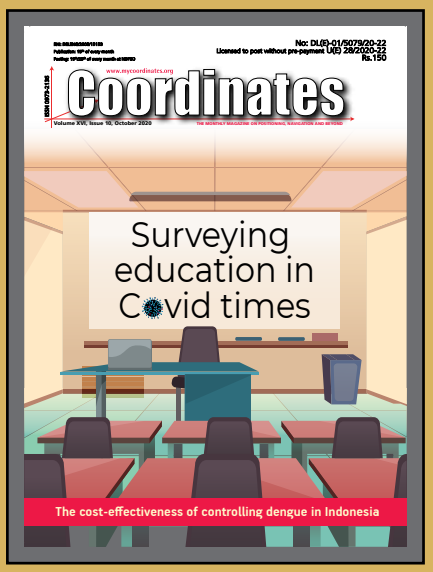
March 2022

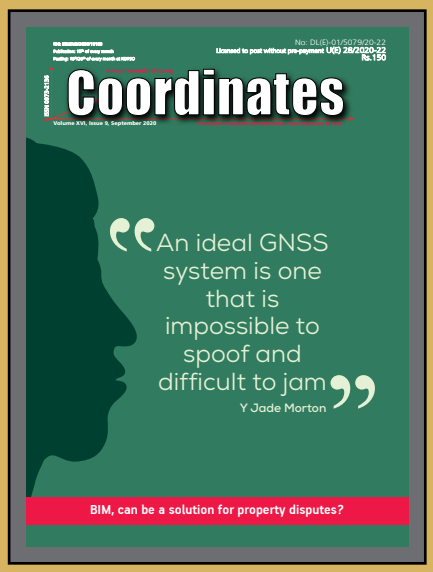
Munich Satellite Navigation Summit 2022
7-9 March
Munich, Germany
munich-satellite-navigation-summit.org

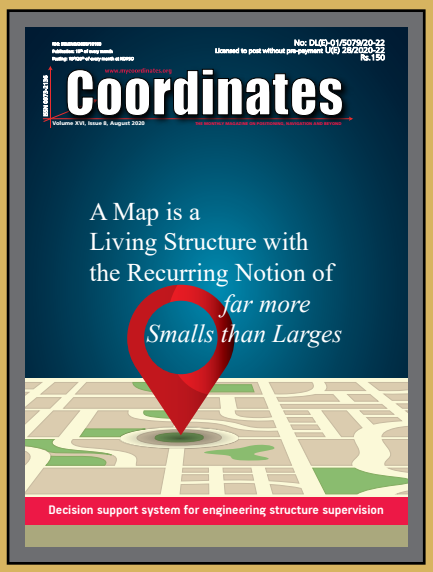
IGRSM 2022
8-9 March
Virtual Conference
Kuala Lumpur Malaysia
www.igrsm.org

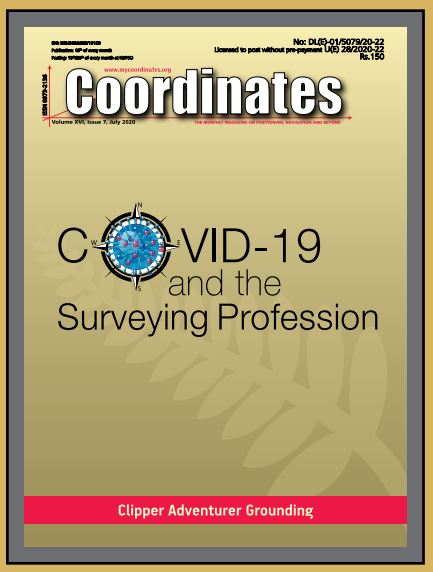


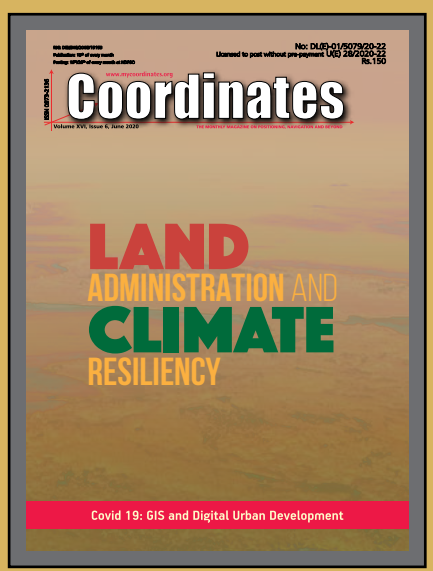


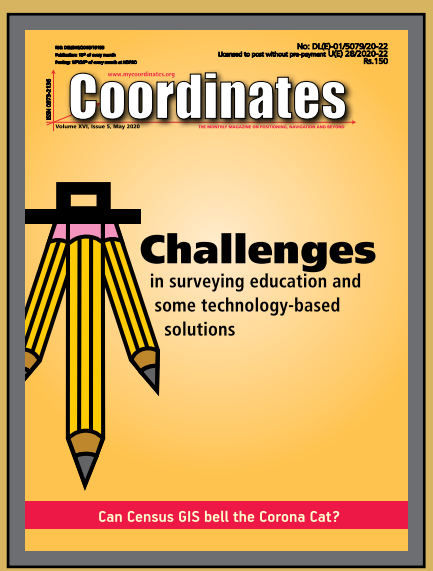












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