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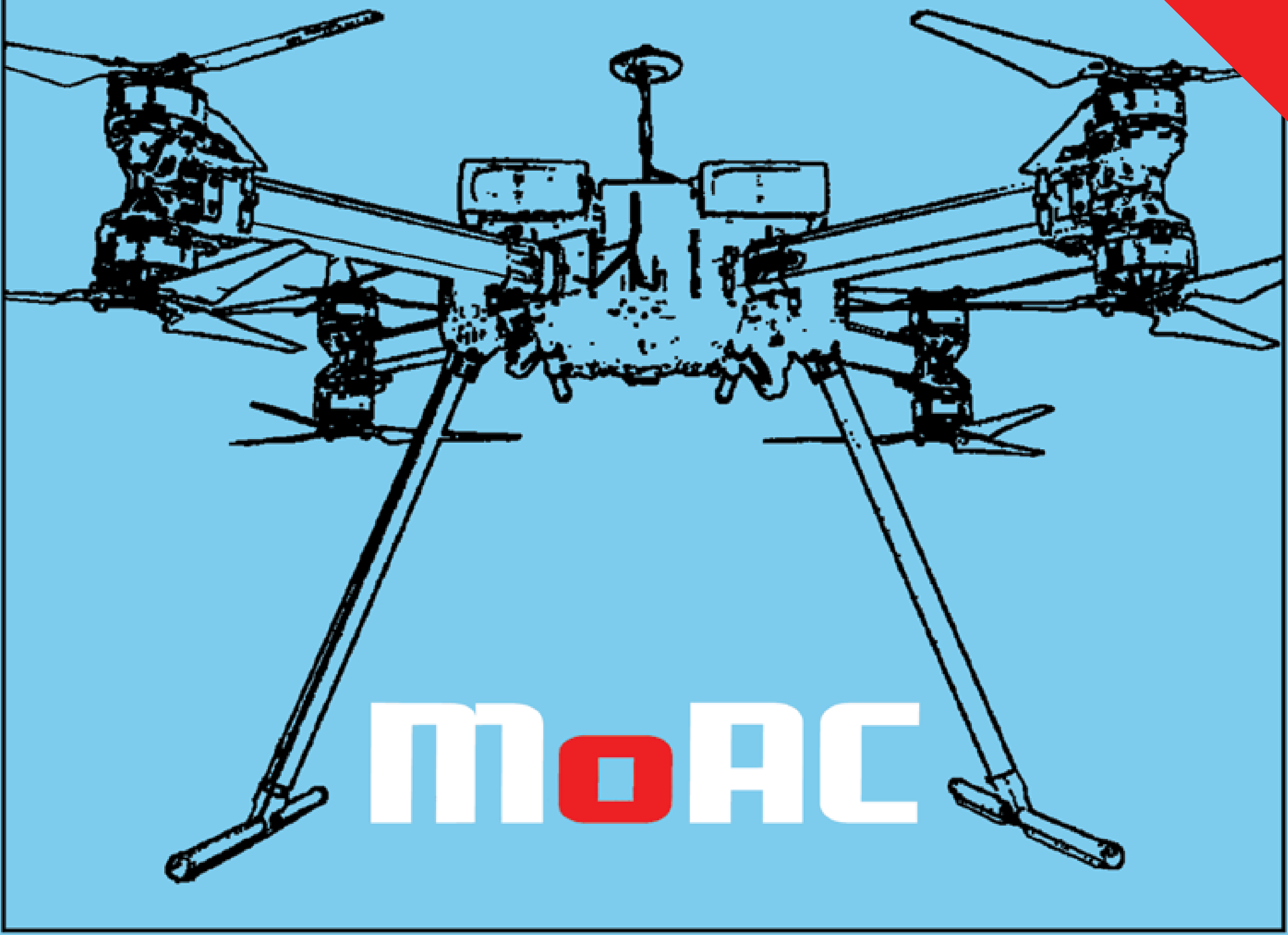
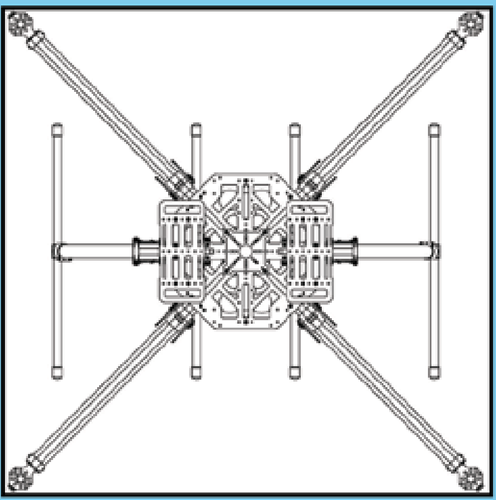
MONOGRAPH

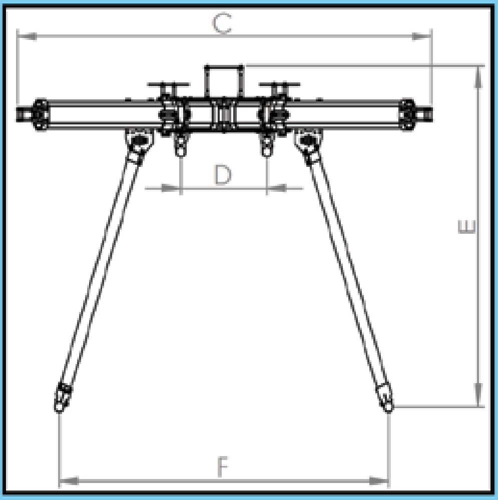
Overview and Current Status of Remote Sensing Applications Based on Unmanned Aerial Vehicles (UAVs)

PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING

The official journal for imaging and geospatial information science and technology







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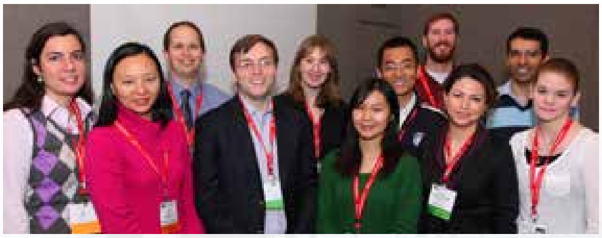

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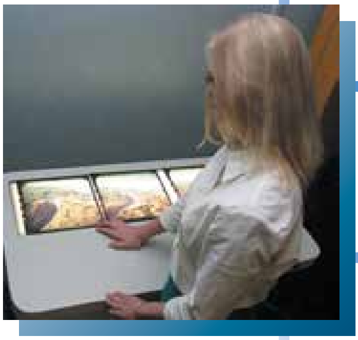

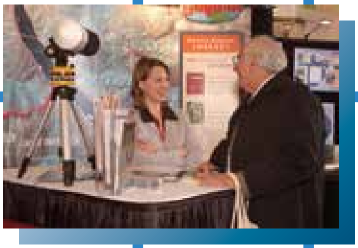

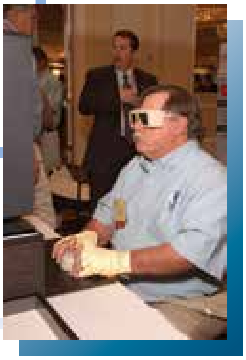

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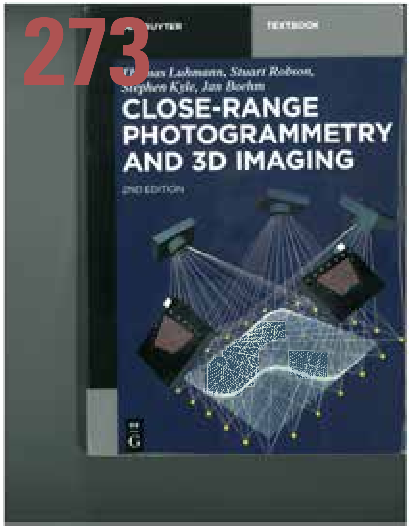
HIGHLIGHT ARTICLE



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PEER-REVIEWED ARTICLES

SPECIAL MONOGRAPH

281 Overview and Current Status of Remote Sensing Applications Based on Unmanned Aerial Vehicles (UAVs)

Gonzalo Pajares

A monograph presenting an overview of the current status of UAVs and remote sensing applications based on unmanned aerial platforms equipped with a combination of specific sensors and instruments, including an expanded list of technical references.

LETTER FROM ALAN MIKUNI PE CP, ASPRS PAST PRESIDENT AND CO-CHAIR UAS MAPPING 2015 RENO

Dear Reader,

If you mention the term “Unmanned Aircraft Systems” or “UAS” in casual conversation with family, friends, or colleagues, you might get the reaction of either a puzzled look or a “what’s that?” (or both). In an immediate attempt to clarify, you might say “you know, ***drones***.” Then, you will probably observe some level of recognition, likely based on perceptions gleaned from news reports from foreign military theaters-of-operation, and less-than-positive.

Of course, for those of us in the geospatial professions, UAS are rapidly becoming familiar features of how research, applications, and business are conducted in the imaging and geospatial technology world. Another term, “disruptive technology,” aptly describes what effect UAS are having on ASPRS disciplines. The traditional means by which data are acquired, how the data are processed, and the array of applications for aerial data have been altered dramatically. Interest in the fundamentals of ASPRS disciplines seems to be on the rise, and, as one ASPRS member recently exclaimed, photogrammetry is alive and well, thank goodness! Aerial mapping will never be the same.

It gives me great pleasure to introduce two papers devoted to the topic of UAS in this issue of *PE&RS*. The Highlight Article, “Testing a Small UAS for Mapping Artisanal Diamond Mining in Africa”, by Katherine C. Malpeli and Peter G. Chirico, presents a fascinating look at a particularly unique application for UAS. Aspects of an adage related to UAS, that they are useful for work that is “dull, dirty, or dangerous”, are demonstrated by the authors of this paper. The work of aerial image acquisition of so-call “blood diamond” mines and mining operations is dangerous for the human scientists in strife-torn West and Central Africa. Such activities are similarly dangerous for the quad-copter UAS as native birds see the aircraft as a territorial threat, much like the human residents of the region view human intruders. In his monograph on UAS, “Overview and Current Status of Remote Sensing Applications Based on Unmanned Aerial Vehicles (UAVs)”, Gonzalo Pajares provides you an extensive treatise on available remotely piloted aircraft, in particular, UAS platforms, associated airborne sensors, their capabilities, and a glimpse at the variety of applications for them. The author describes the variety of fixed-winged and rotary-winged UAS, e.g., multi-rotor “copters”. He also delves into the variety of sensors like RGB, infrared, multispectral and hyperspectral cameras, LiDAR, and radar/synthetic-aperture radar. He also describes a variety of applications for these intriguing systems. The author concludes by providing hundreds of references to enable the reader to investigate further. Please enjoy and learn from the perspectives

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PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING

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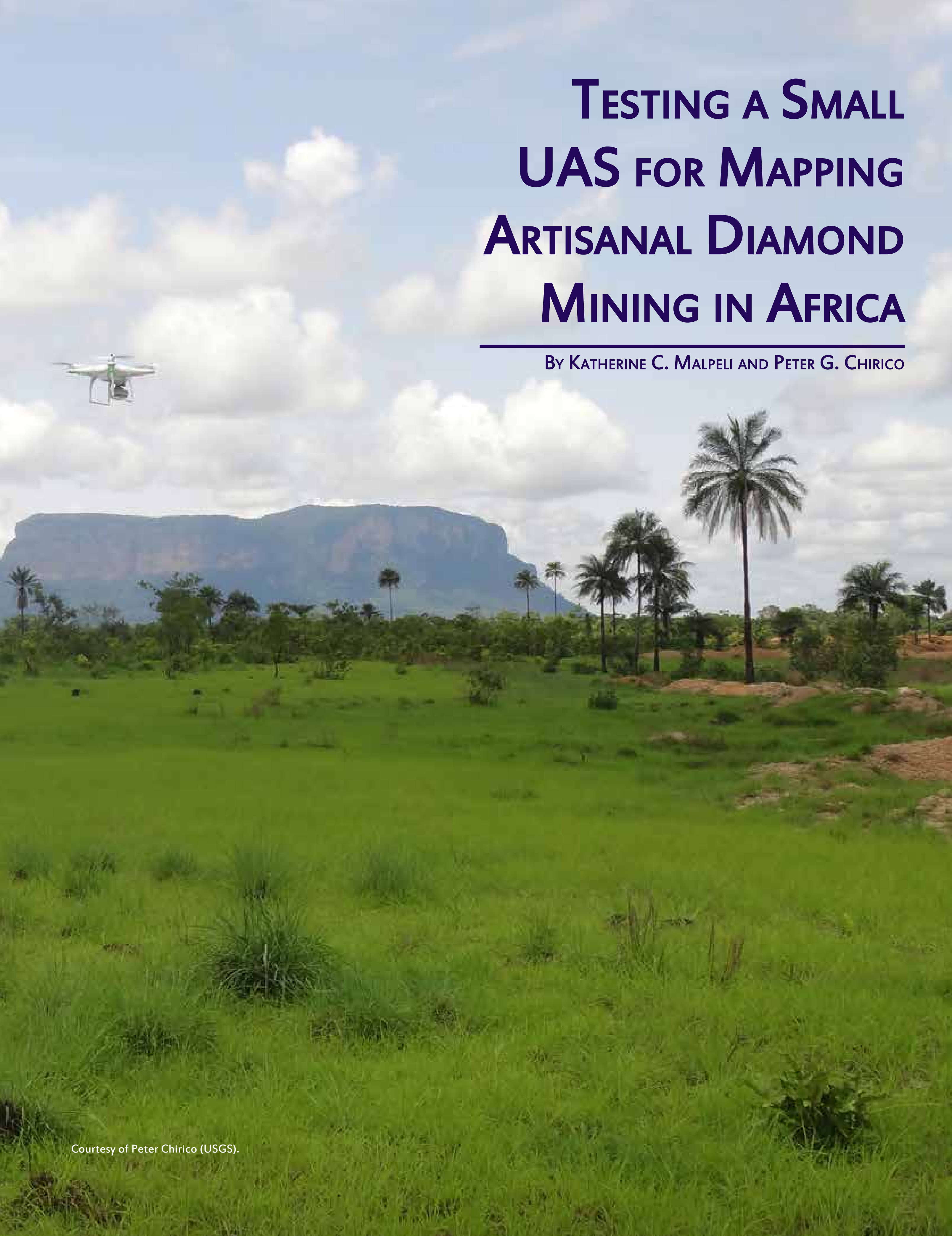
Testing a Small UAS for Mapping Artisanal Diamond Mining in Africa

By Katherine C. Malpeli and Peter G. Chirico



Courtesy of Peter Chirico (USGS).

Courtesy of Souleymane Diallo (USAID PRADDII).

INTRODUCTION—CONFLICT DIAMONDS, ARTISANAL MINING, AND REMOTE SENSING

Remote sensing technology is advancing at an unprecedented rate. At the forefront of the new technological developments are unmanned aircraft systems (UAS). The advent of small, lightweight, low-cost, and user-friendly UAS is greatly expanding the potential applications of remote sensing technology and improving the set of tools available to researchers seeking to map and monitor terrain from above. In this article, we explore the applications of a small UAS for mapping informal diamond mining sites in Africa. We found that this technology provides aerial imagery of unparalleled resolution in a data-sparse, difficult to access, and remote terrain.

This work stems from a long-term project carried out by the U.S. Geological Survey (USGS), the U.S. Department of State (DOS), and the U.S. Agency for International Development (USAID) in support of the Kimberley Process (KP), an international initiative aimed at preventing the flow of conflict diamonds. Concerns that natural resources were being used to fund conflicts first surfaced in the late 1990s and early 2000s during the brutal civil wars in Sierra Leone, Liberia, and Angola. During these conflicts, profits from diamond mining were exploited by rebel groups to purchase arms and finance the wars (Le Billon, 2008). The terms "blood diamonds" and "conflict diamonds" evolved as a result and were popularized to describe such scenarios. In an effort to halt the trade of conflict diamonds, the KP was initiated in 2003 to impose and enforce regulations on diamond producing, importing, and exporting countries. As of 2014, 81 countries were members of the KP.

Countries whose diamonds are produced through artisanal and small-scale mining (ASM), an activity in which individuals use only simple tools to mine, face unique challenges in adhering to the KP's regulations. ASM sites are often remote and spread over vast territories, and the diamonds found are frequently sold into informal networks, making it very difficult to track production – a key requirement of the KP. To support the KP and DOS in monitoring efforts, the USGS has been conducting country-scale diamond resource and production assessments in West and Central Africa since 2007.

In recent years, there has been an increased push by national governments and the international development community to formalize ASM. Formalization involves legalizing ASM, registering miners, delineating mining zones, and establishing a legal flow chain through which production is intended to move. The ability to map and monitor artisanal diamond mining sites is a necessary step towards achieving formalization. Doing so helps to identify where mining is taking place, the extent of activities, the amount of production, and how the activity and production change over time. The USGS is currently spearheading research on the applications of remote sensing technologies for mapping artisanal diamond mining sites. The USGS is using high-resolution panchromatic and multispectral satellite imagery, in combination with field observations, to successfully identify ASM activities and estimate the production in diamond mining zones throughout the region (Chirico and Malpeli, 2013; Kauffmann et al., 2013). While a useful tool, satellite imagery has its limitations, such as atmospheric constraints (cloud cover, haze, smoke, etc.), temporal resolutions that fail to capture the dynamic nature of ASM sites, and spatial resolutions that can be inadequate for identifying fine-scale features. With the advent of small, low-cost, and user-friendly UAS, the USGS and USAID recently began collaborating to explore the application of this technology for mapping and monitoring ASM. Specifically, the team is using UAS technology to support USAID's Property Rights and Artisanal Diamond Development (PRADD) project's efforts to formalize ASM in Guinea. In June 2014, a USGS and USAID team used a small UAS to map artisanal diamond mining sites in the Forecariah Prefecture of western Guinea (Figure 1). Building on a previously completed country-scale assessment of Guinea's diamond deposits in 2012 (Chirico et al., 2012), this current effort seeks to create detailed site maps and generate very-high resolution digital elevation models (DEMs) of the region to better inform diamond production evaluations.

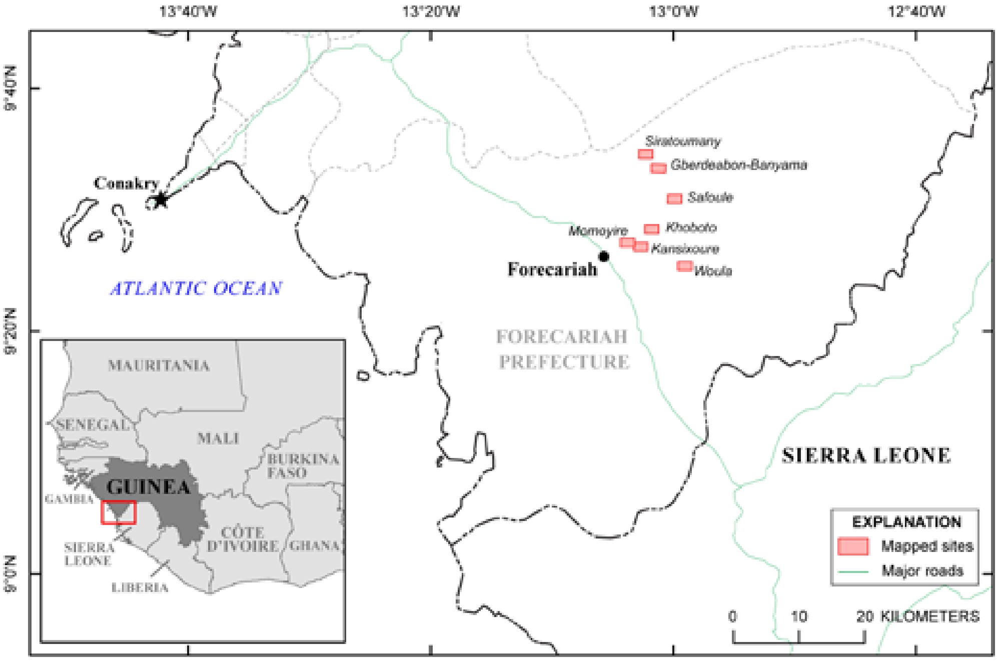


Figure 1. Map of the Forecariah Prefecture study area in western Guinea.

UAS for Environmental Research

While the development of UAS technology has been driven largely by military requirements, it is increasingly being employed for civilian applications (Hardin and Jensen, 2011). Researchers began investigating the development of remotely-piloted vehicles for environmental applications in the 1980s. Early research encountered numerous challenges such as navigation and aircraft control difficulties, limited payload capacities, and difficulties in ensuring complete target coverage (Tomlins, 1983). Many of these challenges have since been addressed, and within the past 7 to 8 years small UAS technology capable of environmental data collection has become widely available. Today, researchers are using UAS for a variety of environmental purposes including precision agriculture, soil assessments, and vegetation, habitat, and biodiversity monitoring (Hardin and Hardin, 2010).

While numerous types of UAS are now available, most environmental research employing this technology is carried out with small, lightweight aerial vehicles that have short flight ranges and limited flying altitudes (Paneque-Gálvez et al., 2014; Hardin and Jensen 2011). Such UAS can only carry light payloads, so small consumer-grade (non-metric) digital cameras are the most commonly used sensors. However, UAS technology is continually evolving, and infrared, multispectral, thermal, hyperspectral, LiDAR, and Synthetic Aperture Radar (SAR) systems are also being tested on UAS (Hardin and Jensen, 2011).

Using a UAS to Map Artisanal Mining Activities in Guinea

In June 2014, a joint USGS/USAID team employed a small (350 mm x 350 mm; 670 g) battery-powered rotary-wing quadcopter to collect data at seven artisanal diamond mining sites in the Forecariah Prefecture of western Guinea (Figures 1 and 2). Two lightweight (74 g) non-metric digital cameras were tested on the quadcopter. The first camera (Camera 1) had a 2.5 mm wide-angle lens (101.96° horizontal Angle of View (AOV), 84.6° vertical AOV) and was used to collect nadir, oblique, and reverse oblique videography at a rate of 30 frames per second. The second camera (Camera 2) had a 7.5 mm low distortion lens (44.72° horizontal AOV, 33.39° vertical AOV) and was used to collect nadir still frame photography at a rate of 2 frames per second. The quadcopter was powered with 2200 milliampere-hour (mAh) or 2600 mAh lithium-polymer (LiPo) batteries, which enabled a flight time of 8-12 minutes per battery.

Figure 2. A PRADD team member flying the UAS at an artisanal diamond mining site.

The quadcopter was flown multiple times over each site, at an altitude of 100 m. At this flying height, Camera 2 had a field of view (FOV) height of 64 m and width of 85 m, resulting in still photography with a horizontal image resolution of 2.13 cm at nadir. However, in our evaluations of the imagery, we calculated an image resolution range of 2-4 cm, due to slight variations in flying height and view angle. A photo collection rate of 2 frames per second resulted in about 800 photos per 0.1 km^2, with a forward overlap of greater than 80% and a sidelap of approximately 60%. Utilizing a wide-angle lens on Camera 1 to collect video resulted in a wider FOV height and width (102 m and 256 m, respectively) but a lower image resolution (Figure 3).

Courtesy of Peter Chirico (USGS).

Figure 3. A mosaic of several oblique images of the Siratoumany site in the Forecariah Prefecture study area in western Guinea captured from video collected using the wide-angle lens camera.

BENEFITS OF USING A UAS

While UAS are currently being used for numerous environmental mapping applications, to our knowledge this project represents the first time a UAS has been used for mapping ASM. One of the principle benefits of using a UAS for this application is that very high-resolution data can be collected over a relatively large area in a short amount of time. In this study, the UAS collected data at an approximate rate of 1.5 km² (150 hectares) per hour. Small UAS have low operational flying altitudes (typically 50-300 m) and therefore the resolution of the data significantly enhances visual image analysis (Galvez et al., 2014) (Figure 4). The resolution of the data collected in Guinea allowed us to clearly distinguish active pits from inactive pits, locate and measure piles of extracted gravel and sedimentary layers, and detect changes in water color and sediment properties (Figures 5 and 6). The ability to map an entire site from one or two field locations is particularly beneficial for ASM research, as mine sites are often located in remote areas, can be several square kilometers in size, and sections of sites may be inaccessible or even dangerous for researchers to traverse due to a lack of roads, surficial disturbance due to mining, or other challenging terrain. Utilizing a UAS, the field team was able to acquire complete aerial coverage of a site in under an hour.

(4)

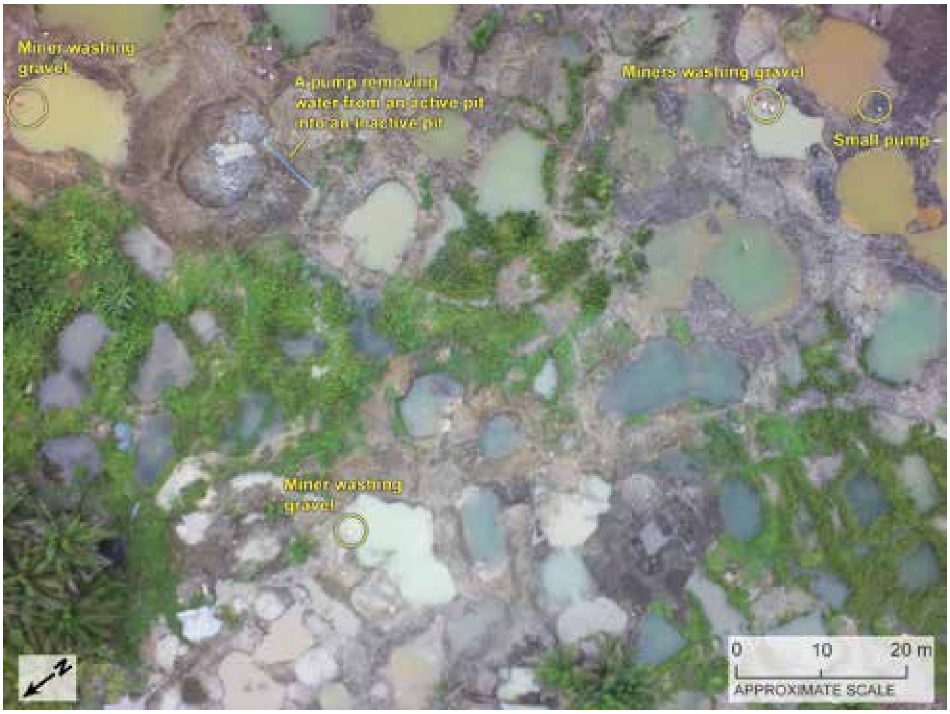


Figure 4. An example of UAS imagery collected at 100 m altitude over the Khoboto site in the Forecariah Prefecture study area in western Guinea.

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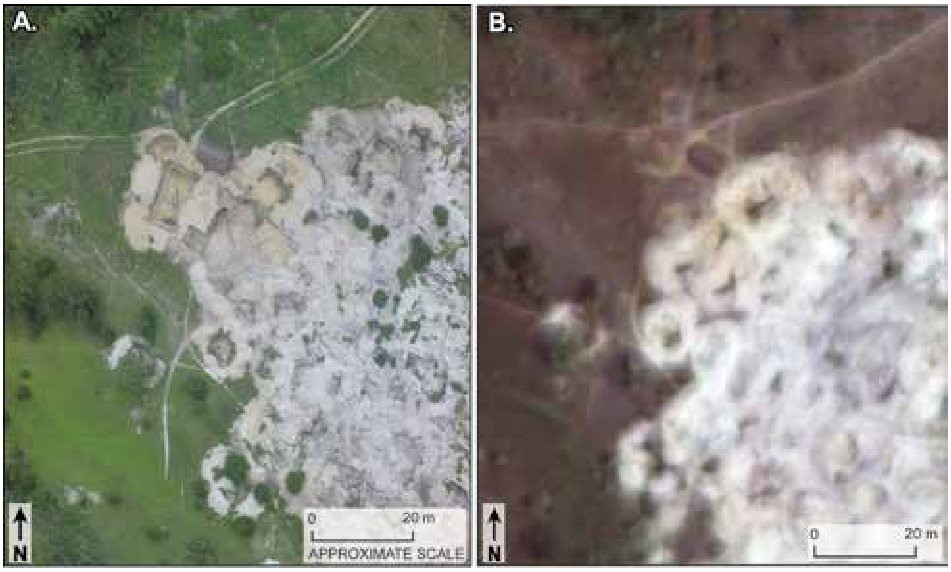

Figure 5. Comparison of the spatial resolution of the UAS imagery (A) collected at the Banyama site in the Forecariah Prefecture in western Guinea with a pan-sharpened high-resolution (0.5 m) multispectral satellite image (B) of the same site.

(6)

Figure 6. A low altitude photo of miners working at a pit in the Forecariah Prefecture study area in western Guinea collected using the UAS.

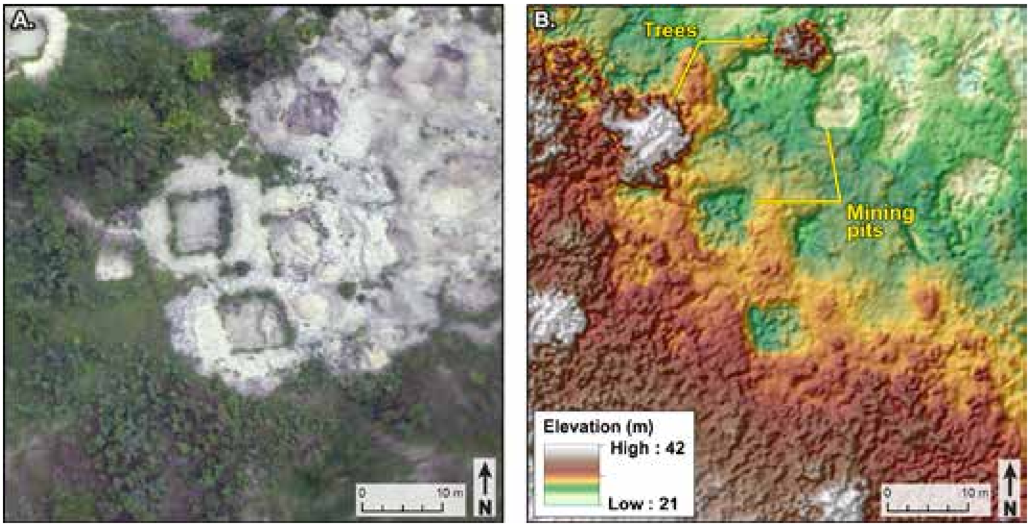

Figure 7. A subset of a UAS image mosaic collected at the Gberdeabon site (A) and a 10 cm resolution digital surface model (DSM) of the same site in the Forecariah Prefecture of western Guinea, derived from the UAS imagery using SfM techniques (B). The DSM incorporates both vegetation and tree cover features as well as ground elevation showing mining pits.

> *"To our knowledge this project represents the first time a UAS has been used for mapping ASM".*

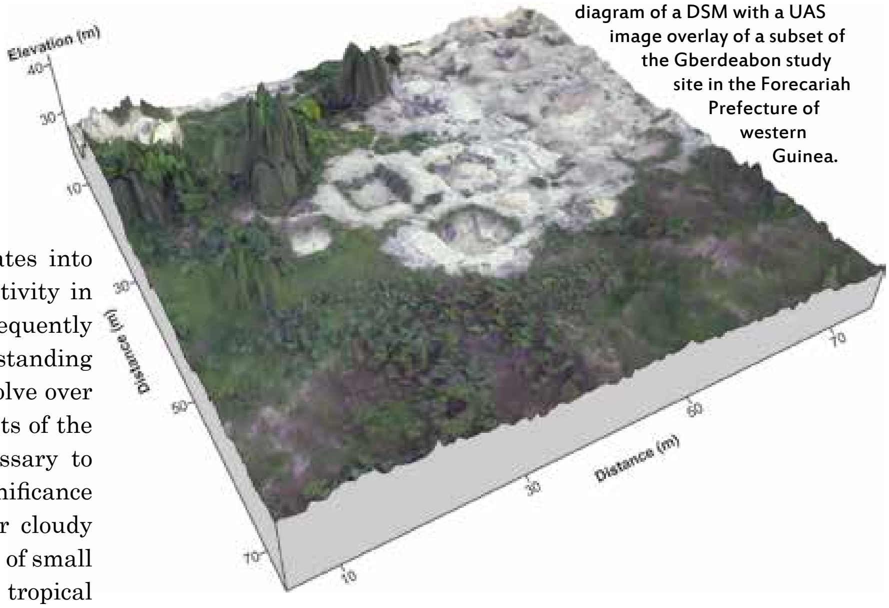

Figure 8. A three-dimensional diagram of a DSM with a UAS image overlay of a subset of the Gberdeabon study site in the Forecariah Prefecture of western Guinea.

This relative ease of data collection also translates into greater survey repeatability. ASM is a dynamic activity in which mine sites change rapidly. The ability to frequently collect imagery of sites will greatly improve our understanding of ASM and how sites, and therefore production, evolve over time. A goal of this project is to conduct repeat flights of the sites within six months to acquire the data necessary to perform a change detection analysis. Of further significance is the ability to collect high-quality imagery under cloudy conditions, due to the low operational flying altitudes of small UAS. This is of particular value when working in tropical climates. Other benefits include the small size of many UAS, which makes transportation into the field easier, as well as the vertical take-off and landing and hovering capabilities of rotary-wing UAS, which improves operability in terrains with dense vegetation and disturbed topography.

DATA ANALYSIS

Analysis of the UAS data collected in Guinea is currently underway. The nadir aerial images are being used to develop 10 cm resolution DEMs of each mine site. High-resolution ortho-image mosaics are being developed from the nadir image frames, the DEM data, and from field GPS control points. Together, the ortho-images and DEMs will help us to model the geomorphology of the terrain and enable us to better understand and identify areas of diamond deposition in the region. Products are being generated using both structure from motion (SfM) and traditional photogrammetric software algorithms, so that comparisons can be made to evaluate the costs and benefits of data processing in each environment (Figures 7 and 8). In addition, the PRADD project is utilizing the aerial videos and oblique still imagery captured using Camera 1 (wide angle lens) to conduct participatory mapping with local communities in Forecariah Prefecture to delineate mining and agricultural zones. This will assist with the formalization of property rights, thus reducing local-scale conflicts over land use.

IDENTIFIED CHALLENGES

While we identified numerous benefits to using UAS technology for collecting data at ASM sites, we also encountered several challenges. First, if a UAS has never been flown before in the country, as was the case in Guinea, there will likely be no set of established protocols to follow to acquire approval. Therefore, it was the team's responsibility to identify a process for contacting the appropriate authorities in Guinea to acquire permission to fly the UAS. This involved receiving signed letters from the Minister of Mines and Geology, the Minister of Transportation, and consent from the ministers of Defense and the Interior.

This step was achieved several months prior to fieldwork by U.S. Embassy and USAID staff based in Guinea. Equally as important as acquiring permission at the national government level was informing local communities near the field sites about the planned UAS mission. Because UAS in many parts of the world may be perceived as synonymous with military drones, it was critical that we educate the local population about the mission. To accomplish this, prior to fieldwork PRADD staff traveled to villages and mining sites to conduct a public relations campaign to notify local populations that the UAS would be flown in the area and to explain why it was being flown and what to expect. During the flight missions the team immediately downloaded and played video collected by the UAS for miners and villagers as a follow-up to the information campaign and to let them see their local landscapes from a birds-eye perspective. These steps added significant time to the field mission, but were essential to gaining the trust of local populations.

Other challenges are unique to flying a UAS in a developing country or remote location. In Guinea, there was no consistent source of power available for the team to recharge the LiPo and camera batteries. Electricity was available for only a few hours each night via generator, so the field team needed to plan accordingly to procure enough fuel and generator time to charge the equipment. In addition, due to the remote nature of the field sites, the team needed to prepare in advance for foreseeable maintenance problems, and thus brought spare parts for the UAS, such as extra propellers, engines, and a basic toolset.

Weather conditions also posed challenges. While the UAS can collect data under cloud cover, moderate to strong winds and rain remain limiting factors and prohibit data collection. Conversely, flying in bright sun conditions made maintaining constant visual contact with the UAS, a necessary safety parameter, more difficult. Finally, an interesting challenge that was not foreseen by the team involved interactions with territorial birds. In particular, the pied crow (*Corvus albus*), found throughout sub-Saharan Africa, exhibited territorial harassing behavior on more than one occasion with the UAS. Given the small size of the UAS and the relatively large size of the crow and other predatory birds in West Africa, interactions of this nature are of a concern, though are perhaps unavoidable.

The Implications of UAS Technology for ASM Research

The very high-resolution imagery and videography collected by the UAS is facilitating the development of image maps and terrain models of the mining sites and surrounding areas in the Forecariah Prefecture at an unprecedented scale. An abundance of information is being gathered from these products, ranging from the scope of mining activities, the location of mining within the landscape, the amount of activity at each site, the impact of mining on the surrounding environment, and the type of mining activities being conducted at the time of image collection. The immediate application of this information will be to assist the PRADD project in working with the Guinean government to select appropriate zones to parcel for artisanal mining based on diamond potential, an important step towards formalization and resource governance. Interpretation of the data will also assist with the identification of abandoned mine sites that can be remediated into other income-generating activities, such as fish farming and vegetable gardens, thus helping to reduce the long-term environmental degradation caused by ASM.

We are only beginning to uncover the many potential applications of UAS technology for environmental remote sensing. For ASM research, it will greatly enhance our ability to map and monitor difficult-to-access and dynamic mining sites. The level of detail garnered from UAS flight data is unparalleled and will serve diverse purposes, from helping governments and local communities allocate land for mining, to enabling researchers to identify landforms with greater diamond potential. Small UAS technology is still a relatively new innovation and therefore still faces challenges; however, UAS provide many advantages over traditional satellite remote sensing, and its applications will only expand as the technology continues to grow.

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BRYAN CONNER, MAPJOY

INTERVIEW

Bryan Conner is co-founder and CEO of MapJoy LLC.

What is your background and how did MapJoy come about?

A North Carolina native, I made my way to the University of Colorado Boulder for undergraduate work in Geography with an emphasis on Remote Sensing, Cartography, and GIS. Upon graduation, I was hired by a fellow CU alumnus as the second employee at a Photogrammetry startup where I logged thousands of hours compiling data with Zeiss P1, P3, and P33 Planicomp Analytical Stereo-plotters and Bentley Microstation 3D CAD Design and Modeling Software. The firm was recognized for its high quality work and expanded its service offerings to include project planning, ground control services, and aerial triangulation.

Prior to returning to graduate school at UNC's Kenan-Flagler Business School, I acquired Interferometric Synthetic Aperture Radar (IFSAR) data on four continents and sold turn-key Multi Telemetry Remote Sensing Ground Stations for a Southern California firm. Most recently, I've served as head of Finance for a North Carolina software company. Through UNC, I met MapJoy's Co-Founder, Will Potts, whose background is in Computer Science and Electrical Engineering. Our complementary backgrounds and awareness of a credible market opportunity lead to MapJoy.

Real Estate buyers/investors are currently more technologically savvy, self-sufficient, and informed than ever before. Everyday consumers are more open to using 3D technology. MapJoy was founded to help sellers better market their Real Estate assets, reach a larger potential buyer pool, and accelerate sales and leasing velocity. The software and service helps buyers make quicker and more informed purchasing decisions due to the increased transparency of the space and high quality information. Consumers want more than flat 2D photographs, lackluster virtual tours, and sometimes confusing 2D floorplans. Users love 3D environments as they get a better feel for the flow and layout of a property, which mitigates disappointment during the buy-sell process.

What is MapJoy?

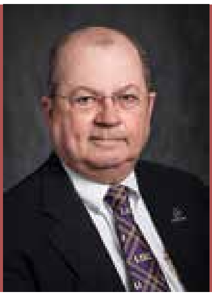
MapJoy is a 3D mapping services firm focused on delivering innovative marketing solutions in the Real Estate industry. Today, MapJoy uses several COTS hardware devices for data acquisition while developing proprietary software and value added offerings customers demand. MapJoy captures 3D high resolution panoramic imagery and underlying structural data to allow clients to navigate indoor environments. At MapJoy, our focus is on quality and excellent customer service. We are hiring and are always looking for high quality partnerships so please reach out to us!

What markets are best served with this technology?

Selected markets we are selling to are Vacation Rentals, Commercial Office, Historic Preservation, Public Use, Multifamily, Insurance, and Emergency Services. We have found early success in industries where the 3D models save significant time and expense from unneeded site visits, or where the models can be repurposed for many uses. In vacation rental our clients can showcase the same model to many customers over a number of sales cycles. In Multifamily we map unique floorplans for our clients and they are able to use the 3D models to represent similar rooms throughout the property. As the technology becomes more pervasive and data acquisition becomes commoditized, we anticipate many physical assets will maintain 3D virtual representations for property management and space planning.

What other services is MapJoy planning to release in the future?

MapJoy is focused on providing premium 3D models to our customers and we pride ourselves on quality with regard to lighting, staging, and post production. As a result, our 3D models contain minimal superfluous data and data dropout. We plan to expand our service to include marketing performance analytics. As a service provider, we are nimble and will work to integrate with other COTS providers as this technology becomes commoditized and increasingly mobile.



GRIDS & DATUMS

BY Clifford J. Mugnier, CP, CMS

REPUBLIC OF SUDAN

"Archaeological excavation of sites on the Nile above Aswan has confirmed human habitation in the river valley during the Paleolithic period that spanned more than 60,000 years of Sudanese history. By the eighth millennium *B.C.*, people of a Neolithic culture had settled into a sedentary way of life there in fortified mud-brick villages, where they supplemented hunting and fishing on the Nile with grain gathering and cattle herding. Contact with Egypt probably occurred at a formative stage in the culture's development because of the steady movement of population along the Nile River. Skeletal remains suggest a blending of negroid and Mediterranean populations during the Neolithic period (eighth to third millenia *B.C.*) that has remained relatively stable until the present, despite gradual infiltration by other elements. Northern Sudan's earliest historical record comes from Egyptian sources, which described the land upstream from the first cataract, called Cush, as "wretched." For more than 2,000 years after the Old Kingdom (ca. 2700-2180 B.C.), Egyptian political and economic activities determined the course of the central Nile region's history. Even during intermediate periods when Egyptian political power in Cush waned, Egypt exerted a profound cultural and religious influence on the Cushite people.

"Over the centuries, trade developed. Egyptian caravans carried grain to Cush and returned to Aswan with ivory, incense, hides, and carnelian (a stone prized both as jewelry and for arrowheads) for shipment downriver. Egyptian traders particularly valued gold and slaves, who served as domestic servants, concubines, and soldiers in the pharaoh's army. Egyptian military expeditions penetrated Cush periodically during the Old Kingdom. Yet there was no attempt to establish a permanent presence in the area until the Middle Kingdom (ca. 2100-1720 B.C.), when Egypt constructed a network of forts along the Nile as far south as Samnah, in southern Egypt, to guard the flow of gold from mines in Wawat. Around 1720 B.C., Asian nomads called Hyksos invaded Egypt, ended the Middle Kingdom, severed links with Cush, and destroyed the forts along the Nile River. To fill the vacuum left by the Egyptian withdrawal, a culturally distinct indigenous kingdom emerged at Karmah, near present-day Dunqulah. After Egyptian power revived during the New Kingdom (ca. 1570-1100 B.C.), the pharaoh Ahmose I incorporated Cush as an Egyptian province governed by a viceroy. Although Egypt's administrative control of Cush extended only down to the fourth cataract, Egyptian sources list tributary districts reaching to the Red Sea and upstream to the confluence of the Blue Nile and White Nile rivers. Egyptian authorities ensured the loyalty of local chiefs by drafting their children to serve as pages at the pharaoh's court. Egypt also expected tribute in gold and slaves from local chiefs. Once Egypt had established political control over Cush, officials and priests joined military personnel, merchants, and artisans and settled in the region. The Coptic language, spoken in Egypt, became widely used in everyday activities. The Cushite elite adopted Egyptian gods and built temples like that dedicated to the sun god Amon at Napata, near present-day Kuraymah. The temples remained centers of official religious worship until the coming of Christianity to the region in the sixth century. When Egyptian influence declined or succumbed to foreign domination, the Cushite elite regarded themselves as champions of genuine Egyptian cultural and religious values.

"By the eleventh century B.C., the authority of the New Kingdom dynasties had diminished, allowing divided rule in Egypt, and ending Egyptian control of Cush. There is no information about the region's activities over the next 300 years. In the eighth century B.C., however, Cush reemerged as an independent kingdom ruled from Napata by an aggressive line of monarchs who gradually extended their influence into Egypt. About 750 B.C., a Cushite king called Kashta conquered Upper Egypt and became ruler of Thebes until approximately 740 B.C. His successor, Painkhy, subdued the delta, reunited Egypt under the Twenty-fifth Dynasty, and founded a line of kings who ruled Cush and Thebes for about a hundred years. The dynasty's intervention in the area of modern Syria caused a confrontation between Egypt and Assyria. When the Assyrians in retaliation invaded Egypt, Taharqa (688-663 B.C.), the last Cushite pharaoh, withdrew and returned the dynasty to Napata, where it continued to rule Cush and extended its dominions to the south and east. Egypt's succeeding dynasty failed to reassert control over Cush. In 590 B.C., however, an Egyptian army sacked Napata, compelling the Cushite court to move to a more secure location at Meroe near the sixth cataract. For several centuries thereafter, the Meroitic kingdom developed independently of Egypt, which passed successively under Persian, Greek, and, finally, Roman domination. During the height of its power in the second and third centuries B.C., Meroe extended over a region from the third cataract in the north to Sawba, near present-day Khartoum, in the south. The pharaonic tradition persisted among a line of rulers at Meroe, who raised stelae to record the achievements of their reigns and erected pyramids to contain their tombs. These objects and the ruins of palaces, temples, and baths at Meroe attest to a centralized political system that employed artisans' skills and commanded the labor of a large work force. A well-managed irrigation system allowed the area to support a higher population density than was possible during later periods. By the first century B.C., the use of hieroglyphs gave way to a Meroitic script that adapted the Egyptian writing system to an indigenous, Nubian-related language spoken later by the region's people. Meroe's succession system was not necessarily hereditary; the matriarchal royal family member deemed most worthy often became king. The queen mother's role in the selection process was crucial to a smooth succession. The crown appears to have passed from brother to brother (or sister) and only when no siblings remained from father to son.

"Although Napata remained Meroe's religious center, northern Cush eventually fell into disorder as it came under pressure from the Blemmyes, predatory nomads from east of the Nile. However, the Nile continued to give the region access to the Mediterranean world. Additionally, Meroe maintained contact with Arab and Indian traders along the Red Sea coast and incorporated Hellenistic and Hindu cultural influences into its daily life. Inconclusive evidence suggests that metallurgical technology may have been transmitted westward across the savanna belt to West Africa from Meroe's iron smelteries. Relations between Meroe and Egypt were not always peaceful. In 23 B.C., in response to Meroe's incursions into Upper Egypt, a Roman army moved south and razed Napata. The Roman commander quickly abandoned the area, however, as too poor to warrant colonization. In the second century A.D., the Nobatae occupied the Nile's west bank in northern Cush. They are believed to have been one of several well-armed bands of horse- and camel-borne warriors who sold protection to the Meroitic population; eventually they intermarried and established themselves among the Meroitic people as a military aristocracy. Until nearly the fifth century, Rome subsidized the Nobatae and used Meroe as a buffer between Egypt and the Blemmyes. Meanwhile, the old Meroitic kingdom contracted because of the expansion of Axum, a powerful Abyssinian state in modern Ethiopia to the east. About A.D. 350, an Axumite army captured and destroyed Meroe city, ending the kingdom's independent existence.

"The emergence of Christianity reopened channels to Mediterranean civilization and renewed Nubia's cultural and ideological ties to Egypt. The church encouraged literacy in Nubia through its Egyptian-trained clergy and in its monastic and cathedral schools. The use of Greek in liturgy eventually gave way to the Nubian language, which was written using an indigenous alphabet that combined elements of the old Meroitic and Coptic scripts. Coptic, however, often appeared in ecclesiastical and secular circles. Additionally, early inscriptions have indicated a continuing knowledge of colloquial Greek in Nubia as late as the twelfth century. After the seventh century, Arabic gained importance in the Nubian kingdoms, especially as a medium for commerce. The Christian Nubian kingdoms, which survived for many centuries, achieved their peak of prosperity and military power in the ninth and tenth centuries. However, Muslim Arab invaders, who in 640 had conquered Egypt, posed a threat to the Christian Nubian kingdoms. Most historians believe that Arab pressure forced Nobatia and Muqurra to merge into the kingdom of Dunqulah sometime before 700. Although the Arabs soon abandoned attempts to reduce Nubia by force, Muslim domination of Egypt often made it difficult to communicate with the Coptic patriarch or to obtain Egyptian-trained clergy. As a result, the Nubian church became isolated from the rest of the Christian world.

"In January 1899, an Anglo-Egyptian agreement restored Egyptian rule in Sudan but as part of a condominium, or joint authority, exercised by Britain and Egypt. The agreement designated territory south of the twenty-second parallel as the Anglo-Egyptian Sudan. Although it emphasized Egypt's indebtedness to Britain for its participation in the re-conquest, the agreement failed to clarify the juridical relationship between the two condominium powers in Sudan or to provide a legal basis for continued British presence in the south. Britain assumed responsibility for governing the territory on behalf of the khedive" *(Library of Congress Country Study, 2015).*

Slightly less than one-fifth the size of the United States, Sudan is bordered by the Central African Republic (175 km) (*PE&RS*, March 2012), Chad (1,360 km) (*PE&RS*, August 2014), Egypt (1,275 km) (*PE&RS*, November 2008), Eritria (605 km), Ethiopia (769 km) (*PE&RS*, March 2003), Libya (383 km) (*PE&RS*, June 2006), and South Sudan (2,184 km) in which "Sudan-South Sudan boundary represents 1 January 1956 alignment; final alignment pending negotiations and demarcation; final sovereignty status of Abyei region pending negotiations between Sudan and South

Sudan." Sudan is a generally flat, featureless plain with a desert that dominates the north *(World Factbook, 2015).*

"Since 1899 cadastral mapping in the Sudan has been concentrated along the banks of the Nile from the Egyptian frontier to latitude 13º N., in the towns, and in the area of the Gezira, south of Khartoum, where cotton has been developed. These surveys were controlled by theodolite and steel tape either in the form of traverses or rectangulation. The early triangulation was used mainly to control topographical surveys, for it was essential to cover the whole country as rapidly as possible with a series of maps on scale 1:250,000. As a consequence much of this early triangulation is of a relatively low order of accuracy, indifferently marked on the ground, and unfit for inclusion in a framework for medium and large scale mapping. Brigadier Winterbotham's visit to the Sudan in 1929 led however to a revival of interest in the geodetic triangulation of the 30th Arc of Meridian. Lieut.-Col. S. L. Milligankk then Director of Surveys, made persistent efforts in face of the poverty of the country and the economic crisis to start the great work, and a length in 1935 a party under R.C. Wakefield went into the field. Progress was steady for five seasons and, by the time war intervened, two sections of the chain had been completed between the Egyptian frontier and latitude 13° 30´ N" *(Base Measurement in the Anglo-Egyptian Sudan, D. F. Musey, M.A., Empire Survey Review, Vol. X, No. 72, 1949, pp. 66-74).*

Geodetic work started in the Sudan in 1935 as part of the survey of the "Arc of the 30th Meridian" from Norway to South Africa. The geodetic work in the Sudan was an extension of previous work through Europe and ended finally in Egypt; the origin for the Egyptian work was considered in establishing an origin for the work in the Sudan. The fundamental origin of the Egyptian chain is "Venus" station near Cairo. In 1874 a number of expeditions were led by British scientists to various European colonies in Africa and the Indian Ocean in order to simultaneously observe the transit of Venus for the purpose of precisely determining differences in longitude. Helwân Observatory situated on Az Zahra Hill in the Al Moqattam Hills, Qalyûbîya of Cairo was utilized for the observations, and the station was termed "F_1" where: Φ_o = 30º 01´ 42.8591″ N, Λ_o = 31º 16´ 33.6″ East of Greenwich, the initial LaPlace azimuth being measured from Station O_1 (Helwân) to Station B_1 (Saccara), α_o = 72º 42´ 01.20″ from South, and H_o = 204.3 m, based on mean sea-level at Alexandria. The Egyptian work was extended to Adindan which is just north of the Sudan border. The geographical positions of this station were computed according to the Hayford figure of 1909 where: a = 6,378,388 m, $^1/_f$ = 297.

"In Mongalla minor triangulation completed a chain from the western limit of the survey along the Sudan-Uganda boundary to the Nile and was connected at Opari to the 1927 survey. Various disconnected surveys, from Gwynn's of 1901 to Whitehouse's of 1926, have been incorporated, and the values of all trigonometrical stations have been re-computed. When smoke from grass-fires caused the temporary cessation of the Mongalla survey, the inspector moved to Upper Nile and fixed astronomically some positions between the Nile and the Pibor at the request of the Egyptian Irrigation Department; latitude observations were made to a minimum of twenty pairs of stars, and longitude was determined by wireless time signals. Five new trigonometrical stations were fixed in the Nuba Mountains, and the position of Dilling was found by Astro-radio means to differ from that previously accepted by 7.01″ in latitude and 29.106″ in longitude. In a minor triangulation in the Hadendowa District of Kassala a base of 7,000 metres was measured near Tendera Wells and connected to Jebels Asoteriba and Musmar, which were fixed in 1902. A native surveyor was sent to make a plane-table survey in the Qala' en Nahl neighbourhood and measured a base of 3,500 meters along the Sennar-Gedaref railway, connecting up to Jebel Beila fixed by Gwynn in 1904" *(Sudan Government: Annual Report of the Survey Department for the Year 1930, Empire Survey Review, pp. 139 & 140).*

For the Sudan part of the arc, the origin of the geodetic work was in southern Egypt near Abu Simbel, south of Lake Nasser, at station Adindan where: Φ_o = 22º 10´07.1098″N, Λ_o = 31º 29´21.6079″ East of Greenwich, azimuth of line Z_v – Y_v: α_o = 58° 14´ 28.45″, deflection of the vertical: ξ = +2.38″, η =-2.51″, and the ellipsoid of reference was the Clarke 1880 *(modified)* where: a = 6,378,249.145 m and $^1/_f$ = 293.465. The Blue Nile Datum of 1958 is the established classical datum of Sudan and much of North Africa. Adindan is the name of the origin, it is <u>not</u> the name of the datum; a most common mistake found in many "reference works."

In the period between 1935 and 1945 all the geodetic work in the Sudan was concentrated on the Arc of the 30th Meridian as it would be the basis for the whole program. During this period, the arc was carried south to latitude 13° 45´ N. Throughout this work, the English-made Tavistock theodolite was used in the observations with sixteen sets of angles observed *(A Geodetic Datum for The Sudan, M.O.Adam, Cornell University Thesis, June,1967, 95 pages).*

The other part of the Arc of the 30th Meridian from latitude 13° 45´ N to the boundary with Uganda was observed together with a number of first and second order chains during the period 1943 to 1952. Assistance on this work was given by the U.S. Army Map Service; one Party Chief was the late William Parkhurst that used a Wild Heerbrugg theodolite and moved from place to place via camel *(Personal communication, c.a. 1963).*

Based on a *very* recent analysis of 13 collocated points in the Sudan, the 3-parameter transformation **from** WGS84 datum **to** the Blue Nile Datum of 1958 (Adindan origin) has updated the NIMA values to ΔX = +162.6 m ± 0.3025 m, ΔY = +15.1 m ± 0.3025 m, ΔZ = –204.5 m ± 0.3025 m; RMS = 1.0906 m *(Common Point Coordinates Transformation Parameters Between Adindan (Sudan) New Ellipsoid and the World Geodetic System 1984 (GPS Datum) Coordinates Compared with Parameters of the American National Imagery and Mapping Agency (NIMA), Abdelrahim Elgizouli Mohamed Ahmed, International Journal of Advanced Research in Engineering and Applied Sciences, ISSN: 2278-6252, Vol. 2, No. 9, September 2014, pp. 26-39).*

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MAPPINGMATTERS

YOUR QUESTIONS ANSWERED

The layman's perspective on technical theory and practical applications of mapping and GIS

BY Qassim A. Abdullah, Ph.D., PLS, CP**

QUESTION:

Q: I was among the attendees of your session on the new ASPRS Map Accuracy Standards during the last ASPRS fall conference held in Denver in November 2014. Could you please elaborate more on the new standards, its similarity with the previous standards and how to use it?

Anonymous

Dr. Abdullah: PART II: In the January 2015 issue of "Mapping Matters", I introduced PART I of my answer to the question by introducing the new standard and the reasons behind its development. In the last couple decades, the Geospatial community witnessed tremendous changes in the mapping process due to the rapid advancements in data acquisition sensor technologies and the maturity of processing software and algorithms. Such changes created the opportunity and need for new standards in evaluating and quantifying the quality and the accuracy of the more sophisticated mapping products. Naturally, such changes in the mapping process deemed all previous legacy map accuracy standards; such as ASPRS Map Accuracy Standard of 1990 and the National Map Accuracy Standard (NMAS); obsolete and unable to represent today's more sophisticated mapping processes and products.

PART I also introduced the horizontal accuracy measure for Geospatial Data and how the accuracy class definition does not limit the classes to a certain ranking or certain number of classes as the legacy standards did. In PART II I will continue the discussions on horizontal accuracy and will introduce the vertical accuracy measure for Geospatial Data.

In PART I of my answer, I included an example that was provided in the new standard on how to convert a horizontal accuracy measure, according to the new standard, to its equivalent in the legacy ASPRS standard of 1990. A similar example was provided in the new standard on how to relate a horizontal accuracy measure, according to the new standard, to its equivalent in the legacy National Map Accuracy Standard (NMAS) of 1947 as illustrated in the following example:

Example 2: Converting the horizontal accuracy of a map or orthoimagery from the new ASPRS 2014 standard to the legacy of 1947.

Given: a map or orthoimagery with an accuracy of $RMSE_x = RMSE_y$ = 15 cm according to the new 2014 standard, compute the equivalent accuracy and map scale according to the legacy National Map Accuracy Standard (NMAS) of 1947, for the given map or orthoimagery.

Solution:

1. Because the accuracy figure of $RMSE_x = RMSE_y$ = 15 cm is relatively small, it is safe to assume that such accuracy value is derived for a map with a scale larger than 1:20,000. Therefore, we can use the factor "1/30 inch."
2. Use the formula CMAS (CE90) = 2.1460 × $RMSE_x$ = 2.1460 × $RMSE_y$
   CE 90% = 2.1460 × 15 cm = 32.19 cm
3. Convert the CE 90% to feet
   32.19 cm = 1.0561 foot
4. Use the NMAS accuracy relation of CE90% = 1/30 inch on the map, compute the map scale
   CE 90% = 1/30 × (ground distance covered by an inch of the map), or ground distance covered by an inch of the map = CE 90% × 30 = 1.0561 foot × 30 = 31.68 feet
5. The equivalent map scale according to NMAS is equal to 1" = 31.68' or 1:380

Horizontal Accuracy Requirements for Elevation Data

When it comes to the horizontal accuracy for elevation data, the new standard distinguishes between two sources of elevation data. Those are the ones produced from the photogrammetric process such as stereo-compilation and auto-correlation or the ones produced from modern scanning sensors such as LiDAR and IFSAR.

Photogrammetric Elevation Data: For elevation data derived from photogrammetric means such as stereo compilation or image-based auto-correlation, the horizontal accuracy equates to the horizontal accuracy class that would apply to planimetric data or digital orthoimagery produced from the same source imagery and the same aerial triangulation/INS solution. Therefore, if the horizontal accuracy class for digital orthoimagery or planimetric data produced from certain imagery is $RMSE_x$ and $RMSE_y$ equal to10-cm, then the horizontal accuracy for any elevation data such as break lines, mass points, spot heights, or point cloud derived from stereo-pairs generated from the same imagery using the same aerial triangulation/INS solution will also equate to $RMSE_x$ and $RMSE_y$ of 10-cm.

LiDAR Elevation Data: For the first time, the new standard provides users with a measure to estimate the horizontal accuracy of data derived from LiDAR. The new standard recognizes that the horizontal error in LiDAR derived elevation data is largely a function of positional error as derived from the Global Navigation Satellite System (GNSS), attitude (angular orientation) error (as derived from the INS) and flying altitude; and can be estimated based on these parameters. The standard provides the following equation to estimate the horizontal accuracy for an elevation dataset derived from LiDAR-derived:

$$Lidar\ Horizontal\ Error(RMSE_r) = \sqrt{(GNSS\ positional\ error)^2 + \left(\frac{\tan(IMU\ error)}{0.55894170} x\ flying\ altitude\right)^2}$$

The above equation considers flying altitude (in meters), GNSS errors (radial, in cm), IMU errors (in decimal degrees), and other factors such as ranging and timing errors which are estimated to be equal to 25% of the orientation errors. The values for GNSS errors and the IMU errors can be estimated based on manufacturers' accuracy specifications for that GNSS or IMU unit.

The above equation can also be used to estimate the correct flying altitude if the desired horizontal accuracy figure for LiDAR data is agreed upon:

$$Flying\ Altitude \approx \frac{0.55894170}{\tan(IMU\ error)} \sqrt{(Lidar\ Horizontal\ Error\ (RMSEr))^2 - (GNSS\ positional\ error)^2}$$

Table 2 provides examples on the expected horizontal accuracy for LiDAR data collected from different altitudes.

Table 2 Expected Horizontal Errors (RMSEr) for Lidar Data in Terms of Flying Altitude

Altitude (m)	Positional $RMSE_r$ (cm)	Altitude (m)	Positional $RMSE_r$ (cm)
500	13.1	3,000	41.6
1,000	17.5	3,500	48.0
1,500	23.0	4,000	54.5
2,000	29.0	4,500	61.1
2,500	35.2	5,000	67.6

Although the new standard did not provide a specific equation to estimate the horizontal accuracy of elevation data derived from IFSAR, in my opinion, the above set of equations can safely be used for such purpose despite the different natures of the two technologies. Errors from sensor orientation angles determination, sensor positioning, and flying altitude are the major contributors to errors in the resulting products from these two different technologies assuming that both the LiDAR and IFSAR sensors are well manufactured, well calibrated, and the data were processed correctly.

VERTICAL ACCURACY REQUIREMENTS FOR ELEVATION DATA

The new standards changes the way we classify terrain categories by recognizing only two categories. In situations where the ground surface is not obscured by vegetation or manmade features, the new standard refers to such category as "Non Vegetated" terrain and whenever the terrain surface details are obscured by any feature, the new standard refers to such category as "Vegetated" terrain. Such categorization simplifies the way we deal with the elevation data and represents a departure from the lengthily and sometime meaningless categories used in the past. Similar to the measure used for the horizontal accuracy classes, the new standard measures vertical accuracy in term of Root Mean Squares Error (RMSE) for non-vegetated terrain but uses 95% percentile for vegetated terrain due to the nature of random errors distribution for each case. Table 3 provides the vertical accuracy classes naming convention for any digital elevation data.

> **"such changes in the mapping process deemed all previous legacy map accuracy standards such as ASPRS Map Accuracy Standard of 1990 and the National Map Accuracy Standard (NMAS) obsolete and unable to represent today's more sophisticated mapping processes and products"**

As it is the case with the horizontal accuracy classes, by not limiting the classes to a certain ranking or certain number of classes, the new standard offers great flexibility in accommodating any accuracy level obtained from current or future sensor technologies.

The Non-vegetated Vertical Accuracy at the 95% confidence level in non-vegetated terrain (NVA) is computed by multiplying the accuracy value of the Vertical Accuracy Class (or RMSEz) by 1.9600 while the Vegetated Vertical Accuracy (VVA) at the 95% confidence level in vegetated terrain is computed as the 95th percentile of the absolute value of vertical errors which is approximated to equal or less than 3.0 times the accuracy value of the Vertical Accuracy Class (or RMSEz). The new accuracy term, VVA, refers to all vegetated land cover categories combined, including tall weeds and crops, brush lands, and fully forested areas.

The new standard provides examples on vertical accuracy and other quality criteria for ten common vertical accuracy classes, Table 4. To help users of the new standard during the transition period, the new standard provides examples to relate the ten vertical accuracy classes of Table 4 to their equivalents contours intervals from legacy ASPRS 1990 and NMAS 1947 standards as it is illustrated in Table 5. Contours interval given in Table 5 is provided only for comparison reasons and it should not be used in the new standard to measure vertical accuracy as the new standard no longer endorses the use of contour interval or map scale as indicator for map accuracy.

Table 3 Vertical Accuracy Standards for Digital Elevation Data

Vertical Accuracy Class	Absolute Accuracy			Relative Accuracy (where applicable)		
	$RMSE_z$ Non-Vegetated (cm)	NVA at 95% Confidence Level (cm)	VVA at 95th Percentile (cm)	Within- Swath Hard Surface Repeatability (Max Diff) (cm)	Swath-to-Swath Non-Vegetated Terrain ($RMSD_z$) (cm)	Swath-to-Swath Non-Vegetated Terrain (Max Diff) (cm)
X-cm	≤X	≤1.96*X	≤3.00*X	≤0.60*X	≤0.80*X	≤1.60*X

Table 4 Vertical Accuracy/Quality Examples for Digital Elevation Data

Vertical Accuracy Class	Absolute Accuracy			Relative Accuracy (where applicable)		
	$RMSE_z$ Non-Vegetated (cm)	NVA at 95% Confidence Level (cm)	VVA at 95th Percentile (cm)	Within-Swath Hard Surface Repeatability (Max Diff) (cm)	Swath-to-Swath Non-Veg Terrain ($RMSD_z$) (cm)	Swath-to-Swath Non-Veg Terrain (Max Diff) (cm)
1-cm	1.0	2.0	3	0.6	0.8	1.6
2.5-cm	2.5	4.9	7.5	1.5	2	4
5-cm	5.0	9.8	15	3	4	8
10-cm	10.0	19.6	30	6	8	16
15-cm	15.0	29.4	45	9	12	24
20-cm	20.0	39.2	60	12	16	32
33.3-cm	33.3	65.3	100	20	26.7	53.3
66.7-cm	66.7	130.7	200	40	53.3	106.7
100-cm	100.0	196.0	300	60	80	160
333.3-cm	333.3	653.3	1000	200	266.7	533.3

Table 5 Vertical Accuracy of the New ASPRS 2014 Standard Compared with Legacy Standards.

Vertical Accuracy Class	$RMSE_z$ Non-Vegetated (cm)	Equivalent Class 1 contour interval per ASPRS 1990 (cm)	Equivalent Class 2 contour interval per ASPRS 1990 (cm)	Equivalent contour interval per NMAS (cm)
1-cm	1.0	3.0	1.5	3.29
2.5-cm	2.5	7.5	3.8	8.22
5-cm	5.0	15.0	7.5	16.45
10-cm	10.0	30.0	15.0	32.90
15-cm	15.0	45.0	22.5	49.35
20-cm	20.0	60.0	30.0	65.80
33.3-cm	33.3	99.9	50.0	109.55
66.7-cm	66.7	200.1	100.1	219.43
100-cm	100.0	300.0	150.0	328.98
333.3-cm	333.3	999.9	500.0	1096.49

"for the first time, the new standard provides users with a measure to estimate the horizontal accuracy of data derived from LiDAR."

As is the case for the horizontal accuracy conversion, the new standard provides the following examples to relate vertical accuracy measured according to the new standard to its equivalents in the legacy standards.

Example 3: Converting the Vertical Accuracy of an Elevation Dataset from the New Standard to the Legacy ASPRS Map Standard of 1990.

Given: an elevation data set with a vertical accuracy of RMSEz = 10 cm according to the new standard, compute the equivalent contour interval according to the legacy ASPRS map standard of 1990, for the given dataset.

Solution:

The legacy ASPRS map standard of 1990 states that:

> "The limiting rms error in elevation is set by the standard at one-third the indicated contour interval for well-defined points only. Spot heights shall be shown on the map within a limiting rms error of one-sixth of the contour interval."

Because both standards utilize the same RMSE measure to express the vertical accuracy, then the accuracy of the elevation dataset according to the legacy ASPRS map standard of 1990 is also equal to the given RMSEz = 10 cm.

Using the legacy ASPRS map standard of 1990 accuracy measure of RMSEz = 1/3 x contour interval (CI), the equivalent contour interval is computed according to the legacy ASPRS map standard of 1990 using the following formula:

CI = 3 × RMSEz = 3 x 10 cm = 30 cm with Class 1,
or CI = 15 cm with Class 2 accuracy

However, if the user is interested in evaluating the spot height requirement according to the ASPRS 1990 standard, then the results will differ from the one obtained above. The accuracy for spot heights is required to be twice the accuracy of the contours (one-sixth versus one-third for the contours) or:

For a 30 cm CI, the required spot height accuracy, RMSEz = 1/6 × 30 cm = 5 cm

Since our data is RMSEz = 10 cm, it would only support Class 2 accuracy spot elevations for this contour interval.

(TO BE CONTINUED)

The contents of this column reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the American Society for Photogrammetry and Remote Sensing and/or Woolpert, Inc.

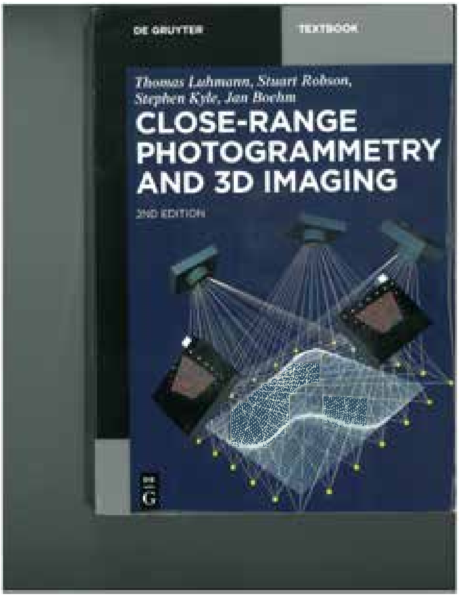
Letter From Alan Mikuni

continued from page 256

provided by these two papers on this latest disruption in the science and technology of ASPRS.

ASPRS, in recognition of the expanding role of UAS in society and The Society, established a UAS Division. ASPRS would appreciate your participation in this new activity. Visit http://uas.asprs.org to learn more. In October 2014, ASPRS' Northern California Region hosted a symposium and technical demonstration devoted exclusively to the topic of mapping using UAS. "UAS MAPPING 2014 RENO" was a gathering of 530 mapping science practitioners, scientists, researchers, manufacturers, software developers, and others interested in mapping with UAS. By most measures, the symposium was a success. I am pleased that, on September 29-30, 2015, ASPRS will be hosting "UAS MAPPING 2015 RENO". Becky Morton (chair of last year's symposium) and I will be co-chairing the 2nd symposium and technical demonstration. Please visit uasreno.org for further information, and I hope to see you in Reno in September!

Alan Mikuni PE CP
ASPRS Past President and Co-chair UAS MAPPING 2015 RENO



Close-Range Photogrammetry and 3D Imaging, 2nd Edition

Thomas Luhmann, Stuart Robson, Steven Kyle and Jan Boehm

Walter De Gruyter GmbH, Berlin/Boston, 2014. xviii and 684 pp. Softcover. $112.00. ISBN 978-3-11-030269-1, e-ISBN 978-3-11-030278-3. 619 figures and 21 tables.

Reviewed by: Stewart Walker, MA, MScE, PhD, MBA, FBCartS, FRGS, FRICS, FRSPSoc, CP, BAE Systems, San Diego, California, USA.

After having found the first edition a surprisingly easy read, not only accessible but packed with interest, your reviewer eagerly anticipated the arrival of this substantial textbook. The first intimation of change is in the list of authors: owing to the sad passing of Ian Harley in 2011, the team has been replenished by Jan Boehm, from the faculty of University College London, a powerhouse of close-range photogrammetry since before the Thompson years, when the discipline was grappling with issues such as the suitability of analog stereoplotters for close-range work and the transition from glass plates to film!

The first edition was published in 2006, an extended version of the German text *Nahbereichphotogrammetrie*, and was well received, leading to the authors being awarded the ISPRS Karl Kraus Medal in 2010. This new edition was required to cover huge advances in computer and imaging technologies – hence the *and 3D Imaging* in the title. The revision has been conscientious and thorough, with a wealth of new material in every chapter – this is no minor revision and prospective purchasers should not vacillate just because they already own the first edition.

After a short introduction chapter, the heart of the 684 page book consists of six long chapters. The sequence of topics treated follows that adopted in the first edition. Chapter 2 covers the underlying mathematics and does well to limit the treatment to methods that will be useful elsewhere in the book. With minor changes in the order, it covers the same topics as the first edition – coordinate systems, coordinate transformations, geometric elements and adjustment techniques. Chapter 3, on imaging technology, the longest in the book, includes both analog and digital systems, with a detailed description of systematic image errors. The chapter begins with the physics of image formation and proceeds through photogrammetric imaging concepts, geometry of the camera as a measuring device, system components, imaging systems, targeting and illumination, and 3D cameras and range systems. Some would quibble with this order, where physical principles and aberrations are followed by systematic errors, after which the imaging systems themselves are described, but it worked well for your reviewer and there is considerably more here than in the first edition.

Chapter 4 covers “Analytical Methods” with sections of roughly equally length on processing single and stereo images followed by a longer section on processing multiple images and bundle adjustment. The chapter ends with shorter sections on panoramic and multi-media photogrammetry.

The 110 pages on digital image processing that comprise chapter 5 are a pleasant read as the coverage is broad and the mathematics not too daunting. The concepts are clearly described and well illustrated. Appropriate space is devoted to least squares matching. While some readers will desire more detail in particular areas, the authors have done well to summarize considerable material, much of it in vibrant research fields, in a compelling way.

The rapid coverage in chapter 6 of measuring tasks and systems reflects the authors’ experience, the chapter proceeds through single-camera, stereoscopic and multi-image systems to passive surface-measuring systems. Two final sections in the chapter are a glimpse of two areas of innovation that command worldwide attention in the geospatial community, mobile mapping systems and unmanned aircraft systems, too young for more than scant coverage in the first edition. It is fluent and well illustrated - readers will expect much more in the third edition!

Chapter 7, “Measurement Design and Quality” is brimming with authoritative advice on project planning and camera calibration. The authors’ almost unequalled experience is brought to bear here as they examine project planning, quality measures and performance testing, and strategies for camera calibration. New material relative to the first edition includes a sub-section on Monte Carlo simulation and importantly an entire section on quality measures and performance. Chapter 8, only 48 pages, on applications, provides instructive samples of completed projects. This is well illustrated and the short commentaries, including notes on typical accuracies, are insightful. The reader gains useful impressions not only of the challenges facing the close-range photogrammetrist but of the remarkable results that can be accomplished for a broad spectrum of clients.

The hundreds of references in chapter 9 begin with more than 50 textbooks and your reviewer was delighted to see the inclusion of *Multiple View Geometry* by Hartley and Zisserman, copies of which seems to adorn the desks of several of his colleagues! The long list of papers is divided into sections that parallel chapters 1 to 8 of the text. While some readers would be more comfortable with conventional references, in parentheses throughout the text, there is no doubt that dipping into chapter 9 for recommendations matching a particular section of the book is straightforward and provides sufficient material for the committed student or practitioner.

The book is generally well presented and is certainly well illustrated, though some diagrams are drab and many require careful study as details, captions and units on axes are often very small. Though the authors attempt to improve readability through consistent notation and four-color printing, resulting in numerous clear, extremely helpful diagrams, many graphics are too small and the color is insufficient: red symbology overlaid on panchromatic images, for example to show the results of matching, is often difficult to discern. In a few cases, the editorial standard slips, for example the odd word has not been changed from German to English, the undergraduate howler “principle point” slipped through at least twice and your reviewer could not find in chapter 9 the references cited in two captions to graphics. The curmudgeonly graphics may indicate an attempt to reduce price by seeking economies: in your reviewer’s copy, despite careful handling, the transparent polythene layer or laminate on the outside of the cover began unattractively to peel before his first complete read! Nevertheless, this edition retains the cachet of a top-rate, prize-winning textbook and includes comprehensive, informative updates. The list price is reasonable for 684 pages of this caliber and aspiring readers may secure lower street prices. *Close-Range Photogrammetry and 3D Imaging* is unhesitatingly recommended to undergraduates, graduate students, researchers and practitioners alike.

CORRECTION

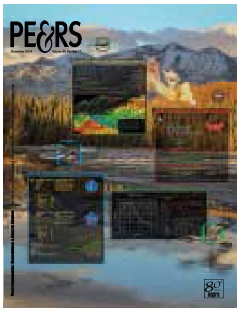
The Citation in the ASPRS Positional Accuracy Standards for Digital Geospatial Data published in the March Issue of *PE&RS* on page 176 should have been as follows:

ASPRS, 2015. ASPRS Positional Accuracy Standards for Digital Geospatial Data, November 2014, *Photogrammetric Engineering & Remote Sensing*, Volume 81, No. 3, 53 p., URL: *http://www.asprs.org/Standards-Activities.html*, doi:10.14358/PERS.81.4.281.281.

HIGHLIGHT ARTICLES

Proposals Wanted

ASPRS is actively seeking Highlight Articles for publication in *PE&RS*



Highlight Articles are meant to extend the impact of *PE&RS* to an even broader range of readers. These articles are semi-technical or non-technical. Each article should address topics of broader interests with greater impact to the geospatial community, and accommodate the interests of readers with a diverse level of geospatial knowledge. Highlight Articles may: review recent or historical developments in technology, industry or academia; discuss new or unusual approaches to common problems; address topics of common concerns or interests.

ASPRS is interested in articles of varied topics but are most interested in articles on:

- Use of UAS for mapping purposes
- Humanitarian activities/relief efforts facilitated by imaging and geospatial technologies
- Sports applications of photogrammetry
- Microsatellite platforms
- Remote sensing projects by international teams
- Imaging and geospatial information programs/initiatives in K-12 education
- Machine vision and artificial intelligence applied to imagery
- Remote sensing applications in the following industries; beer, wine, truffles
- Intelligent transportation systems facilitated by photogrammetry, remote sensing, imaging, and geospatial technologies
- Cybersecurity related to geospatial information
- Privacy issues related to geospatial information (must be balanced and thoughtful presentation)

Please note: Highlight Articles are NOT peer-reviewed articles and should not contain lengthy lists of references or complex equations. They should contain high quality photos and graphics.

For more information, contact: Rae Kelley, Assistant Director-Publications at rkelley@asprs.org.

In Memoriam

JIM MERCHANT

1947-2015

James "Jim" W. Merchant, Jr., professor of geography, died February 27, 2015. He was 67-years old. Among his survivors are wife, Loyola Caron; son, Karl; daughter, Anne; siblings, Rob Merchant, Wes Merchant, Betsy Phelps, Cathy Franklin; and eight nieces and nephews.

"Jim loved UNL and the School of Natural Resources," said SNR director John Carroll. "But more importantly, he loved geography and teaching students. When he was getting sick, the thing he was most concerned about were the students in his courses. We have lost a colleague, friend and true academic."

Born Nov. 10, 1947, to James W. and Emely (Wilson) Merchant, Sr., Merchant was a graduate of Towson State University in Towson, Maryland and the University of Kansas in Lawrence, Kansas, earning undergraduate, graduate and doctoral degrees, respectively.

He began his career as a senior remote sensing specialist with the Kansas Applied Remote Sensing Program at the University of Kansas Space Technology Center. He went on to serve as an assistant professor of geography at the University of Kansas from 1986 to 1989.

In 1989, Merchant moved from Kansas to Nebraska to accept a position as associate director of UNL's Center for Advanced Land Management Information Technologies (CALMIT). The addition of Merchant to the CALMIT team greatly enhanced and broadened the scope of the center's activities. His research in this position focused on land-cover mapping with coarse-resolution satellite data. He went on to serve as director of CALMIT from 2008 to 2011.

In addition to his appointments as a geography professor in SNR and as a research scientist in CALMIT, he held a courtesy professor appointment in the Department of Agronomy and Horticulture, and from 2001-2008 served as the Editor of *PE&RS*, the official journal of the American Society for Photogrammetry and Remote Sensing.

"Jim was thoughtful and articulate in his communications with other scholars and managers, and he worked to stay connected – everyone knew Jim Merchant," said Don Rundquist, emeritus professor and former CALMIT director. "Jim had exceptional skill in dealing with the staff of governmental agencies and he definitely knew how to get things done. He was a major player in the widespread implementation of GIS technology in the state of Nebraska."

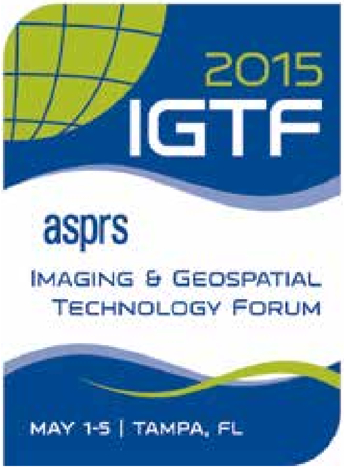
Merchant's research and teaching interests focused on applications of remote sensing and GIS in natural resources management and environmental assessment. He taught undergraduate and graduate courses in these areas, and also offered an annual professional seminar focusing on research methods and professional development in geography.

Merchant was a member of the Association of American Geographers, an elected fellow of the American Society for Photogrammetry and Remote Sensing, and co-founder of the MidAmerica GIS Consortium. Some of his awards include: John Wesley Powell Award from the U.S. Geological Survey (1997), Outstanding Contributions Award from the Nebraska GIS/LIS Association (1999), Career Achievements Award from the MidAmerica GIS Consortium (2004), and Outstanding Service Award from the American Society for Photogrammetry and Remote Sensing (2008).

"Jim was a consummate citizen of both the School of Natural Resources and the geography program at UNL," said Paul Hanson, SNR associate director. "He readily volunteered to serve the unit and within the last several weeks was writing portions of SNR's current Academic Program Review document even though he was months away from his June 2015 retirement. On a more personal note, Jim frequently provided me with advice, particularly in the past year and a half, much of which helped me tremendously in my career. Jim will be greatly missed by those in SNR."

Photo courtesy of University of Nebraska-Lincoln School of Natural Resources

IGTF – RETHINKING THE ASPRS ANNUAL MEETING



If you have not been to an ASPRS conference in a while, come to this one. You will be surprised. This year's annual meeting in Tampa is going to be different. The venue is perfect for us, and we are continuing with the format changes that were so well-received at the recent UAS Mapping 2014 and Pecora 19/ISPRS meetings. The IGTF branding is more than mere marketing – it is a rethinking and reengineering of the ASPRS annual meeting into a more modern and energized conference format.

There will be more plenary talks, more networking time, fewer conflicting technical sessions, more exhibitor-friendly arrangements, and less time away from home. And, we are feeding attendees at lunchtime in the exhibit area. We are not giving up pre-conference workshops and committee meetings, although both will be scheduled more conveniently. We will still have oral sessions, but fewer of them, with increased prestige given to poster presenters. We will still present many, many awards.

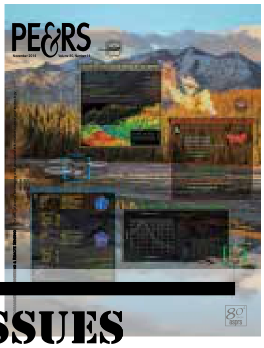
The technical program will be very different, since it is being organized to align directly with the divisions and committees of the Society. Some time slots will emphasize technologies, while others will emphasize applications for those technologies, and still others will focus on cross-cutting themes. For example, there will be sessions on emerging 3D technologies, humanitarian applications of geospatial technology, and an in-depth session on the new ASPRS positional accuracy standards and how they are being applied to make better maps.

Enriching the technical program, ASPRS is happy, once again, to have as conference partners the geospatial experts from NGA and the commercial imagery evaluators/buyers from JACIE (NASA, USGS, NOAA, USDA). ASPRS is also excited to have new groups participating in our conference – the machine vision and pattern recognition folks from IAPR, the energy industry explorationists and environmentalists from GRSG NA, the transportation infrastructure folks from TRB, the geodetic survey and control people from AAGS, the cartographers from CaGIS, and the citizens serving communities from CAP, the US Air Force Auxiliary.

Also new this year is scuba diving in the shark tank. Yes, although few or none may do it, swimming with the sharks at the aquarium during the opening reception is possible, if you are qualified and will pay. The reception, by the way, will be held on the evening before the conference technical sessions start. If you are a "regular" at the annual conference, take note, the timing of activities is also new this year.

Tampa is convenient to reach, and the downtown waterfront venue offers unusual local flavors, superb foamy libation, walkable sightseeing, and deep sea fishing. The sessions will be of high technical quality, some of which may be provocative. The plenary speakers will offer market awareness (Jon Christopherson, with a survey of global commercial space assets), tell you where billions of dollars will be spent (Tim Stryker from the White House), and inspire you with applications of geospatial information that you may not have considered before (surprise speaker). And, on the UAS front, we will hold a joint panel discussion with AUVSI, simulcast between Atlanta and Tampa. Please join me and a thousand other colleagues in Tampa the first week of May.

Registration is open at http://conferences.asprs.org/Tampa-2015/blog. To exhibit or otherwise sponsor the conference, contact Sheldon@asprs.org.



NEW ASPRS POSITIONAL ACCURACY STANDARDS FOR DIGITAL GEOSPATIAL DATA RELEASED

The American Society for Photogrammetry and Remote Sensing (ASPRS) is pleased to announce the release of the new Positional Accuracy Standards for Digital Geospatial Data. The new standards are available at: http://www.asprs.org/Standards-Activities.html. Readers can navigate to the ASPRS Positional Accuracy Standards for Digital Geospatial Data.

The new ASPRS accuracy standards fill a critical need for map users and map makers alike. For centuries, map scale and contour interval have been used as an indication of map accuracy. Users want to know how accurately they can measure different things on a map, and map makers want to know how accurate maps need to be in order to satisfy user requirements. Those contracting for new maps depend on some form of map accuracy standard to evaluate the tradeoff between the accuracy required vs. how much time and expense are justified in achieving it, and then to describe the accuracy of the result in a uniform way that is reliable, defensible, and repeatable.

The new ASPRS standards address recent innovations in digital imaging and non-imaging sensors, airborne GPS, inertial measurement units (IMU) and aerial triangulation (AT) technologies. Unlike prior standards, the new standards are independent of scale and contour interval, they address higher levels of accuracies achievable by the latest technologies (e.g. unmanned aerial systems and lidar mobile mapping systems), and they provide enough flexibility to be applicable to future technologies as they are developed. Finally, the new standards provide cross references to older standards, as well as detailed guidance for a wide range of potential applications.

No prior U.S. accuracy standard comprehensively addresses the current state of mapping technology, which is why the new ASPRS standards were developed. The National Map Accuracy Standards (NMAS), developed in 1947, are still used because they are simple, but there is no scientific correlation between those standards and current mapping methodologies. The ASPRS 1990 Standards were an improvement over NMAS; however, they did not do well in representing the capabilities of Lidar, orthoimagery, digital mapping cameras or other current technologies in wide-spread use today. The National Standard for Spatial Data Accuracy (NSSDA) is a reporting standard that references the old ASPRS 1990 standards and is cross-referenced in the new ASPRS standards. NSSDA provides no accuracy thresholds and does not by itself provide any new or updated guidance on how to select or specify an appropriate accuracy for intended applications.

The new ASPRS standards were developed by the ASPRS Map Accuracy Standards Working Group, a joint committee under the Photogrammetric Applications Division, Primary Data Acquisition Division and Lidar Division, which was formed for the purpose of reviewing and updating ASPRS map accuracy standards to reflect current technologies. A subcommittee of this group, consisting of Dr. Qassim Abdullah, Dr. David Maune, Doug Smith, and Hans Karl Heidemann, was responsible for drafting the document. Draft versions of the standard underwent extensive review, both within ASPRS as well as through public review by other key geospatial mapping organizations, prior to final approval by the ASPRS Board of Directors on November 17, 2014.

ASPRS WELCOMES NEW BOOK REVIEW EDITOR

Dr. Melissa Rura has accepted the Book Review Editor position for *Photogrammetric Engineering and Remote Sensing* (*PE&RS*). For the past five years, this position was previously held by Dr. John Iiames of the U.S. EPA. We would like to thank John for all of his years of valuable service to ASPRS and *PE&RS* and welcome Melissa to our team.

Melissa J. Rura is the program coordinator for the United Methodist Neighborhood Centers of Memphis, Inc. and an alumnus of the University of Texas at Dallas in the department of Geospatial Information Science, where she was the recipient of the Science, Mathematics and Research for Transformation Scholarship for Service from the Department of Defense. She received her master's degree in civil engineering with an emphasis in Geomatics from Purdue University and her bachelor's degrees in mathematics and geography from Murray State University. Her research interests include image analysis, photogrammetry, and spatial statistics, specifically how these topics might be applied and implemented in real-world problems for more informed decision making.

If you are interested in submitting a book for review or being a reviewer for *PE&RS*, please contact Dr. Rura at bookreview@asprs.org.

PRE-REGISTRATION AND CALL FOR ABSTRACTS UAS MAPPING RENO

change is in the air

ASPRS UAS Technical Demonstration and Symposium
September 29 – 30, 2015, Reno Nevada

The second annual technical UAS symposium sponsored by the American Society for Photogrammetry and Remote Sensing (ASPRS) is scheduled for September 29-30, 2015 in Reno, Nevada. Expanding on the highly successful format and events of last year's symposium this year's event will include test flights, UAS data processing, and workshops.

The extended schedule is:

Saturday, September 26	UAS Test Flights
Sunday, September 27	UAS Test Flights
Monday, September 28	UAS Test Flight Data Processing Workshop (hosted by ASPRS) Exhibit Set-Up Opening Reception
Tuesday, September 29	Symposium and Technical Demonstration – Reno Ballroom UAS Live Demonstration
Wednesday, September 30	Symposium and Technical Demonstration – Reno Ballroom
Thursday, October 1	UAS Meetings and Workshops (open for vendors and agencies to host)

Highlights of the symposium:

- Demonstrations (in-flight) of UAS technologies
- Test flights and on-site data processing
- Data processing training workshops
- Collaboration opportunities among users, mapping professionals, government, academia, developers, and UAS product and service providers
- Exhibitor floor including attendee breaks and lunch
- Speakers and presentations on relevant UAS topics

Suggested attendees:

- Users and potential users of UAS products and services
- UAS product and service providers
- Aerial mapping, survey, and geospatial firms
- Companies with UAS interests and business plans
- Government agencies interested and involved in UAS technologies
- Government agencies driving the implementation of UAS policy
- UAS companies- software, hardware, system developers and integrators
- Academia, research institutions, UAS training institutions
- Students in geospatial, survey, robotics, UAS
- The geospatial community
- Geospatial media

Symposium Costs:

- ASPRS Member — $350
- Non-ASPRS Member — $400
- ASPRS Student — $250
- Exhibitor — $650 (includes 2 registrants)

Call for Speakers and Workshops!

We are accepting abstracts for the technical program now. Presentations within the technical program are to be focused on educational aspects of UAS technology and implementation (minimizing product marketing). The program this year will expand the focus on applications of UAS technology as well as innovations in UAS hardware and software. Sign up on the Pre-Registration Link and indicate your interest in presenting, exhibiting, sponsoring, or providing a workshop. http://uasreno.org.

★ ***Pre-Register*** *on the symposium website:* ***http://uasreno.org.***

Early Registration ***Discount of 10% will be available to pre-registrants****!*

IMAGERY PORTAL NAMING CONTEST – IDEAS NEEDED!

The ASPRS Data Preservation and Archiving Committee (DPAC) is nearing completion of work on a portal service for non-federal aerial photography. The portal is a keyword matching system allowing users to locate photography over areas of interest and to access contact information necessary to obtain reproductions or products. The portal will not host the imagery itself; instead, it will help people locate imagery that is NOT online. ASPRS and DPAC are providing this portal to the geospatial community in the hopes that the vast non-federal archives of historic aerial imagery can be more easily searched and utilized.

We need your help in naming this portal service! Please email John Faundeen faundeen@usgs.gov with your ideas. The individual or organization submitting the winning name will be announced at the Tampa Forum and will receive a copy of the book “Our Secret Little War.” Vote early and often!

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ASPRS would like to welcome the following new members!

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Your path to success in the geospatial community

INDUSTRYNEWS

To have your press release published in *PE&RS*, contact Rae Kelley, rkelley@asprs.org.

ANNOUNCEMENTS

Optech is pleased to announce that it will deliver an Optech Galaxy airborne lidar to GeoTerra (formerly 3Di and Bergman Photographic Services), based in Eugene, Oregon. Optech Galaxy's PulseTRAK™ technology will be particularly useful for GeoTerra's upcoming western projects. GeoTerra will benefit greatly from PulseTRAK's™ continuous operating envelope and swath tracking mode. These features specifically eliminate the multipulse challenge by providing seamless and wholly consistent datasets. PulseTRAK™ also provides vertical density of complex targets, such as forests, by capturing up to 8 discrete returns per pulse, enabling GeoTerra to more efficiently model forest structure and understory growth without the need for full-waveform recording.

Optech is pleased to announce delivery of an Optech Lynx SG1 Mobile Mapper™ to Martinez Geospatial, Inc. The vehicle-mounted Lynx SG1, which creates survey-grade engineering models at highway speeds using its two 360° lidar scanners and high-resolution Ladybug® camera, was delivered to the Martinez Geospatial office in Minneapolis, Minnesota. Optech Services personnel trained the Martinez Geospatial team to operate the Lynx and leverage the advanced rectification algorithms and power of the highly automated Optech LMS Lidar Mapping Suite workflow, maximizing their efficiency and ability to consistently deliver highly accurate data to their clients. For further information, please contact www.optech.com.

LizardTech®, a provider of software solutions for managing and distributing geospatial content, has released an updated GeoViewer for Windows application which is the fastest way to view MrSID and JPEG 2000 imagery and includes broad file format support. With this latest release, there are two options available, GeoViewer and GeoViewer Pro. GeoViewer is available as a free application enabling users to display raster imagery, LiDAR point clouds, and vector overlays. New features include the ability to connect to online base maps, combine local data with web map service (WMS) and JPIP sources, export imagery, save projects, and enjoy advanced display options like dynamic range adjustment. Additionally, GeoViewer Pro is available for $50 and allows access to additional functionality, including support for printing, additional projection systems and advanced area measurement tools. To download or purchase GeoViewer, visit our website.

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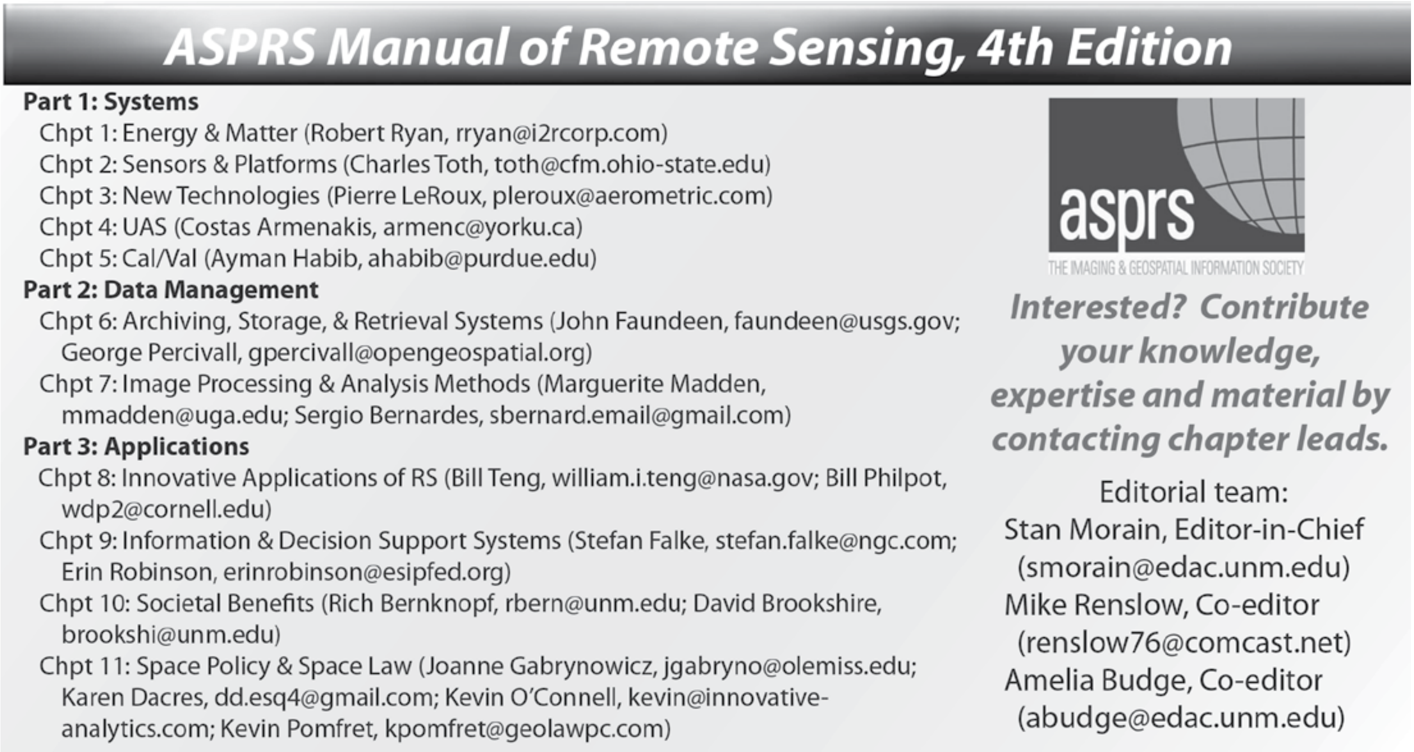

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- Chpt 1: Energy & Matter (Robert Ryan, rryan@i2rcorp.com)
- Chpt 2: Sensors & Platforms (Charles Toth, toth@cfm.ohio-state.edu)
- Chpt 3: New Technologies (Pierre LeRoux, pleroux@aerometric.com)
- Chpt 4: UAS (Costas Armenakis, armenc@yorku.ca)
- Chpt 5: Cal/Val (Ayman Habib, ahabib@purdue.edu)

Part 2: Data Management
- Chpt 6: Archiving, Storage, & Retrieval Systems (John Faundeen, faundeen@usgs.gov; George Percivall, gpercivall@opengeospatial.org)
- Chpt 7: Image Processing & Analysis Methods (Marguerite Madden, mmadden@uga.edu; Sergio Bernardes, sbernard.email@gmail.com)

Part 3: Applications
- Chpt 8: Innovative Applications of RS (Bill Teng, william.i.teng@nasa.gov; Bill Philpot, wdp2@cornell.edu)
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Overview and Current Status of Remote Sensing Applications Based on Unmanned Aerial Vehicles (UAVs)

Gonzalo Pajares

Abstract

Remotely Piloted Aircraft (RPA) is presently in continuous development at a rapid pace. Unmanned Aerial Vehicles (UAVs) or more extensively Unmanned Aerial Systems (UAS) are platforms considered under the RPAs paradigm. Simultaneously, the development of sensors and instruments to be installed onboard such platforms is growing exponentially. These two factors together have led to the increasing use of these platforms and sensors for remote sensing applications with new potential. Thus, the overall goal of this paper is to provide a panoramic overview about the current status of remote sensing applications based on unmanned aerial platforms equipped with a set of specific sensors and instruments. First, some examples of typical platforms used in remote sensing are provided. Second, a description of sensors and technologies is explored which are onboard instruments specifically intended to capture data for remote sensing applications. Third, multi-UAVs in collaboration, coordination, and cooperation in remote sensing are considered. Finally, a collection of applications in several areas are proposed, where the combination of unmanned platforms and sensors, together with methods, algorithms, and procedures provide the overview in very different remote sensing applications. This paper presents an overview of different areas, each independent from the others, so that the reader does not need to read the full paper when a specific application is of interest.

Introduction

Remote sensing refers to the technique of capturing information at a distance (remotely) by specific instruments (sensors). Traditionally, remote sensing has been associated with satellites or manned aircraft with a set of airborne sensors. In the last decade, the increasing developments and improvements in unmanned platforms, together with the development of sensing technologies installed onboard of such platforms, provide excellent opportunities for remote sensing applications. Indeed, they can offer high versatility and flexibility, as compared to airborne systems or satellites, and can operate rapidly without planned scheduling. In remote sensing operations with high human risk, lives can be safeguarded. Additionally, they can fly at low altitudes and slowly, with the ability of acquiring spatial and temporal high resolution data, representing important advantages against conventional platforms that have been broadly used over the years.

Watts *et al.* (2012), Dalamagkidis *et al.* (2012), and Anderson and Gaston (2013) provided a classification and use of platforms where an important issue that determines this classification is the altitude they can fly, ranging from a few meters up to 9,000 m or more. Micro- and nano- air vehicles can fly at low attitudes with limited flight duration because of their battery or energy system's capabilities. There are vehicles with the ability to fly at medium and high altitudes with flight durations ranging from minutes to hours, i.e., from five minutes to 30 hours. The horizontal range of the different platforms is also limited by the power of the communications system, which should ensure contact with a ground station, again ranging from meters to kilometers. Communications using satellite input can also be used, expanding the operational range. There are several different categorizations for unmanned aerial platforms depending on the criterion applied (Nonami *et al.*, 2010). Perhaps the most extensive and current classifications can be found in Blyenburgh (2014) with annual revisions.

An auto platform or remotely controlled platform through a remote station together with a communication system, including the corresponding protocol, constitutes what is known an Unmanned Aircraft System (UAS) (Gertler, 2012). According to Yan *et al.* (2009) and Gupta *et al.* (2013), UAS are considered as the full system, including the aircraft, the remote control station and all of the ground support elements, communication links, air traffic control, and launching and recovery system, as may be required (this is the opinion of the Civil Aviation Authority (CAA, 2015)). Unmanned Aerial Vehicles (UAVs) are included in the category of UAS, i.e., they can fly autonomously, although they can be also remotely controlled (The UAV, 2015). From the standpoint of remote sensing, the equipment of UAS is required for capturing information, which is later conveniently handled (processed, analyzed, or stored), but the term "UAV" is commonly used in remote sensing. Therefore, in this paper, we will refer to UAVs under the perspective of remote sensing operations, including drones, gliders, (quad-, hexa-, octo-) copters, helicopters, balloon-launched gliders, airships, or stratospheric balloon systems and more broadly, any unmanned vehicle with the ability to fly auto-controlled using processors onboard, remotely controlled with human supervision based on a ground station (remotely piloted aircraft; RPA) or through another aerial vehicle under coordination. Certainly, from a strict point of view, all these systems should be considered as RPA systems, because they need human supervision; full autonomy is not generally yet achieved. Nevertheless, as mentioned earlier, throughout this paper we will refer to them as UAVs. This overview is focused on remote sensing applications based on small UAVs of different categories flying at relatively low altitudes with different take-off and landing systems, including Vertical-Take-Off-and-Landing (VTOL), where UAVs operate in different scenarios and situations. The potential use of UAVs

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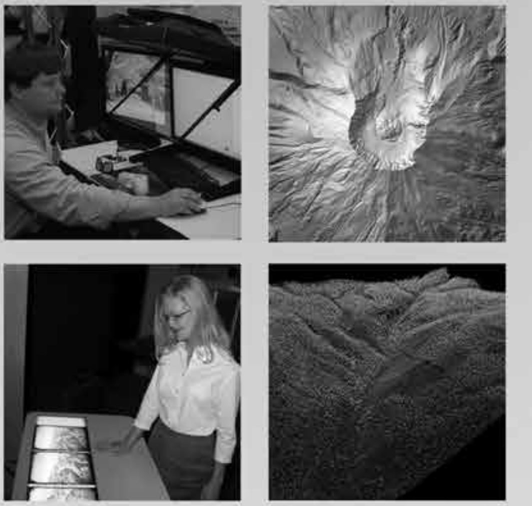

CALENDAR

APRIL

17, GeoByte—Using LiDAR to Study Forests. For more information, visit http://www.asprs.org/GISD-Division/Online-Seminars.html.

MAY

4–8, The Imaging & Geospatial Technology Forum - IGTF 2015 and co-located JACIE Workshop, Tampa, Florida. For more information, visit www.asprs.org.

20-22, The Spatial Data Science Bootcamp, UC Berkeley. or more information, visit http://iep.berkeley.edu/iep?utm_source=GIS_assoc&utm_medium=IEPemail&utm_content=body-top&utm_campaign=spatial2015.

27-28, Geo Business 2015, London, UK. For more information, visit www.GeoBusinessShow.com.

29, GeoByte—A Legal Framework for UAVs: How We Get From Here to There? For more information, visit http://www.asprs.org/GISD-Division/Online-Seminars.html.

JUNE

9-12, Optech Innovative Lidar and Imaging Solutions Conference (ILSC) 2015, Toronto, Canada. For more information, visit www.optech.com/ilsc2015.

19, GeoByte—A Discussion of the USGS Base Lidar Specification, v. 2.0. For more information, visit http://www.asprs.org/GISD-Division/Online-Seminars.html.

AUGUST

23-28, On the Map: American Cartography in 2015, Rio de Janeiro, Brazil. For more information, visit www.icc2015.org/

26-28, 14th International Symposium on Spatial and Temporal Databases 2015 (SSTD 2015), Seoul, South Korea. For more information, visit http://stem.cs.pusan.ac.kr/SSTD2015.

28, GeoByte—USGS Science Data Catalog – Data Visualization, Discovery and Use. For more information, visit http://www.asprs.org/GISD-Division/Online-Seminars.html.

SEPTEMBER

23-24, GIS in the Rockies, Denver, Colorado. For more information, visit http://www.gisintherockies.org/2015/.

28-3 October, ISPRS Geospatial Week 2015, La Grande Motte, France, For more information, visit www.isprs-geospatialweek2015.org.

NOVEMBER

2-5, 10th EARSeL Forest Fire Special Interest Group Workshop, Limassol, Cyprus. For more information, visit, www.ffsig2015.com.

8, Florida ASPRS Symposium, Florida Atlantic University (FAU). For more information, visit http://florida.asprs.org/.

9-13, "COSPAR 2015"—2nd Symposium of the Committee on Space Research (COSPAR): Water and Life in the Universe, Foz do Iguacu, Brazil. For more information, visit, http://cosparbrazil2015.org/.

20, GeoByte—GNSS Derived Heights. For more information, visit http://www.asprs.org/GISD-Division/Online-Seminars.html.

JULY 2016

30–August 7, "COSPAR 2016"—41st Scientific Assembly of the Committee on Space Research (COSPAR), Istanbul, Turkey. For more information, visit http://www.cospar-assembly.org.

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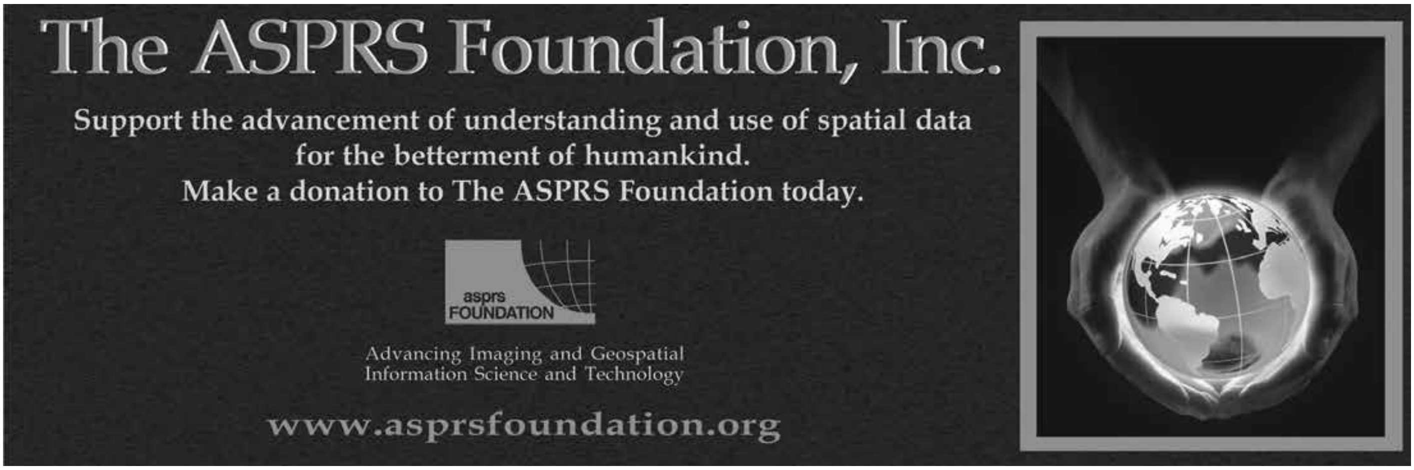

FORTHCOMING ARTICLES

Chris W. Strother, *Marguerite Madden*, *Thomas R. Jordan*, and *Andrea Presotto*, Lidar Detection of the Ten Tallest Trees in the Tennessee Portion of the Great Smoky Mountains National Park.

Muhammad Abdullah Sohl, *Patric Schlager*, *Klaus Schmieder*, and *H.M. Rafique*, Bioenergy Crop Identification at Field Scale Using VHR Airborne CIR Imagery.

Mehdi Mazaheri and *Ayman Habib*, Quaternion-Based Solutions for the Single Photo Resection Problem.

Chinsu Lin, Deriving the Spatiotemporal NPP Pattern in Terrestrial Ecosystems of Mongolia Using MODIS Imagery.

Cody P. Gillin, *Scott W. Bailey*, *Kevin J. McGuire*, and *Stephen P. Prisley*, Evaluation of Lidar-derived DEMs through Terrain Analysis and Field Comparison.

Tammy E. Parece and *James B. Campbell*, Identifying Urban Watershed Boundaries and Area, Fairfax County, Virginia.

Min Wang, *Yanxia Sun*, and *Guanyi Chen*, Refining High Spatial Resolution Remote Sensing Image Segmentation for Man-made Objects through a Collinear and Ipsilateral Neighborhood Model.

Craig Rodarmel, *Mark Lee*, *John Gilbert*, *Ben Wilkinson*, *Henry Theiss*, *John Dolloff*, and *Christopher O'Neill*, The Universal Lidar Error Model.

Deepika Uppala, *Ramana Kothapalli*, *Srikanth Poloju*, *Sesha Sai Mullapudi*, and *Vinay Dadhwal*, Rice Drop Discrimination Using Single Date RISATI Hybrid (RH, RV) Polarimetric Data.

Xiang Shen, *Guofeng Wu*, *Ke Sun*, and *Qingquan Li*, A Fast and Robust Scan Line Search Algorithm for Object-to-Image Projection of Airborne Pushbroom Images.

Kurtis J. Nelson and *Daniel Steinwand*, A Landsat Data Tiling and Compositing Approach Optimized for Change Detection in the Conterminous United States.

Phil Wilkes, *Simon D. Jones*, *Lola Suarez*, *Andrew Haywood*, *William Woodgate*, *Mariela Soto-Berelov*, *Andrew Mellor*, and *Andrew Skidmore*, Understanding the Effects of ALS Pulse Density for Metric Retrieval Across Diverse Forest Types.

GEOBIA SPECIAL ISSUE

Hugo Costa, *Giles M. Foody*, and *Doreen S. Boyd*, Integrating User Needs on Misclassification Error Sensitivity into Image Segmentation Quality.

Xueliang Zhang, *Xuezhi Feng*, and *Pengfeng Xiao*, Multi-scale Segmentation of High-Spatial Resolution Remote Sensing Images Using Adaptively Increased Scale Parameter.

Muditha K. Heenkenda, *Karen E. Joyce*, and *Stefan W. Maier*, Mangrove Tree Crown Delineation from High Resolution Imagery.

Georgia Doxani, *Konstantinos Karantzalos*, and *Maria Tsakiri-Strati*, Object-based Building Change Detection from a Single Multispectral Image and Pre-existing Geospatial Information.

Argyros Argyridis and *Demetre P. Argialas*, A Fuzzy Spatial Reasoner for Multi-Scale GEOBIA Ontologies.

George Mitri, *Mireille Jazi*, and *Devid McWethy*, Assessment of Wildlife Risk in Lebanon Using Geographic Object-Based Image Analysis.

Nies S. Anders, *Arie C. Seijmonsbergen*, and *Willem Bouten*, Rule Set Transferability for Object-Based Feature Extraction: An Example for Cirque Mapping.

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Geospatial Applications of Big Data Analytics

The volume of data created by an ever increasing number of remote sensing platforms and the capability of modern platforms to collect data at ever increasing spatial, spectral, and radiometric resolutions currently exceeds petabytes of data per year and is only expected to increase. The variety of geospatial data available for adding valuable information to traditional remote sensing imagery, including social media and sensors as part of the so-called internet of things (IoT) promises to add information value if it can be effectively integrated. The velocity of all this information is critical, as the information value of all this information degrades if it can not be processed in a timely manner not only for military, intelligence, and other traditional consumers of geospatial data but also for the new breed of geospatial data consumers in areas such as business analysis and logistics. Recent developments in information technology commonly referred to as 'Big Data' along with the related fields of data science and analytics will need to be brought to bear in order to process, analyze and realize the value of the overwhelming amount of geospatial data the remote sensing community is capable of generating.

This special issue of *Photogrammetric Engineering and Remote Sensing (PE&RS)* will focus on the application of advances in Big Data analytic techniques to geospatial applications in the commercial, government and academic remote sensing communities. Papers covering topics including, but not limited to, the following are invited for consideration:

- Technologic advances in hardware, storage, data management, networking and computing models such as virtualization and cloud computing for geospatial applications.
- Creative uses of Big Data innovations such as MapReduce, Hadoop, Big Table and NoSQL in geospatial processing.
- Usage of human-created, machine-created, structured and unstructured data in geospatial analytics including the integration of geospatial information from non-imaging sensors and the Internet of Things (IoT) with more traditional forms of geospatial information.
- Discovery of patterns in large volumes of geospatial data through analytic techniques such as data mining and predictive analytics in applications such as human geography.
- Development of new processing algorithms to handle large volumes of data, for instance through application of functional programming languages such as Lisp, R, and Clojure to geospatial applications.
- Creation of new visualization products that increase the understanding of large and diverse forms of information.

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☐ $50.00 Domestic ☐ $53.00 Canada[1] ☐ $60.00 Foreign

Membership Certificate

Hand-engrossed, framable certificate of membership is availble for additional charge. ☐ $20.00

Member Sponsorship (not mandatory)

Sponsor's Member ID: ______________________________

Sponsor's Name: ______________________________

Member Information

Technical Division Preferences: Number the following 6 ASPRS divisions in order of preference where your primary interests lie so you can be kept up to date on their activities (Order of Preference 1–6).

___ GIS Geographic Information Systems
___ PDA Primary Data Acquisition
___ Lidar Division (new)
___ PA Photogrammetric Applications
___ PP Professional Practice
___ RSA Remote Sensing Applications

☐ New Member ☐ Renewal (ID number ____________________)

☐ Mr. ☐ Ms. ☐ Dr. ☐ other: ____________________

Year of birth*: ______________________________

Name (please print): ______________________________

Check appropriate box for mailing address ☐ home ☐ business

Address: ______________________________

____

Country: ______________________________

Company's name/workplace: ______________________________

Business Phone**: ______________ Home Phone**: ______________

fax**: ______________ e-mail**: ______________

*Required for Associate Members

**DO NOT PUBLISH: ☐ Business Phone ☐ Home Phone ☐ Fax ☐ E-mail

Method of Payment: **Payment must be submitted with application.**

Payment must be made in US Dollars drawn on a US Bank or appropriate credit card. Make checks payable to ASPRS.

☐ Check (Print name on check.)

☐ Visa ☐ MasterCard ☐ American Express ☐ Discover

____
Credit Card Account Number Expires (MO/YR)

____
Signature Date

Total Amount Enclosed: $ ________

Membership dues includes an annual subscription to *PE&RS*. Non-member subscription price is $660.00 (libraries, universities, private companies etc.) Members may NOT deduct the subscription price from dues. ASPRS is an educational organization exempt from taxation under the 501(c) (3) code of the Internal Revenue Service. Dues payments are not deductible as a charitable contribution for federal tax purposes, but may be deductible as a business expense. Please check with your tax preparer.

Dues for Active and Associate domestic members includes Second Class Postage for *PE&RS*. Student members residing in the US, outside of the U.S., including Mexico and Canada, receive a Full digital version of *PE&RS* only.

[1] DUES INCLUDES GST. (ASPRS is required by the Canada Customs and Revenue Agency to collect 5% of the total amount of dues for Canada's Goods and Services Tax — GST #135123065.)

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