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Volume IX, Issue 1, January 2013

THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

UAV

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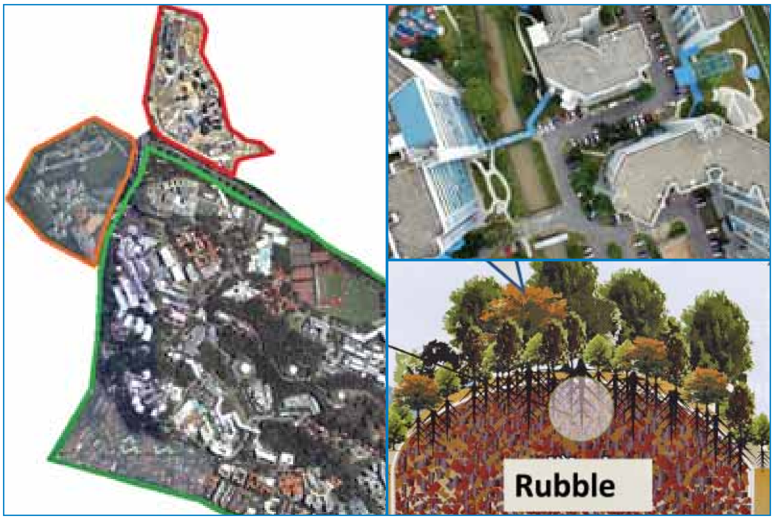

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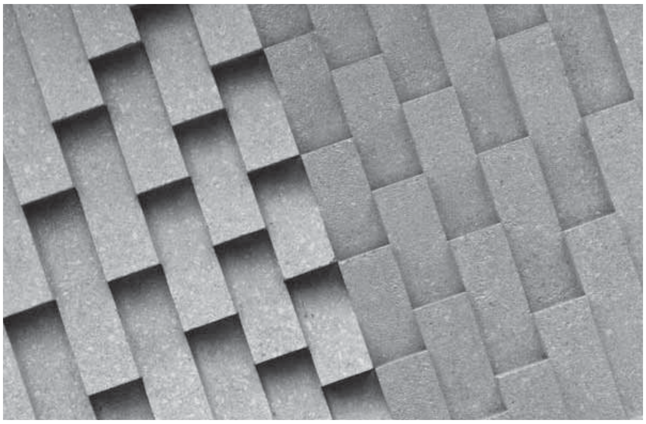

Enigma

Industry, market, growth, potential

Innovation applications

Evolving technology tools

Military, civil, commercial

Safety and security

Spoofing and jamming

Spying and privacy

Rules, regulations, legislations, licenses,…

Resistance and acceptability

UAVs: It is all about innovation, application, apprehension…

It is enigmatic.

Bal Krishna, Editor
bal@mycoordinates.org


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Pilotless Aerial Vehicle Systems: Size, scale and functions

The pressing need is to clarify the policy, regulatory and collateral issues including personal privacy before the industry to develop further

George Cho
Institute for Applied Ecology and Faculty of Applied Science, University of Canberra, Australia

Pilotless aerial vehicle systems (PAVs) have captured many people's imaginations through the media as combat vehicles in various war zones around the world. These vehicles of combat have acquired the pejorative term 'drone' as these aircraft have 'no intelligence' and only respond by attacking positions identified by forward personnel on the ground. Unmanned drones offer warfare with fewer casualties. The drone operator is in little danger of harm being some many of kilometres away from the combat zone.

But, PAVs have also been deployed for non-military work. In Australia, unmanned aerial vehicles (UAVs) as 'eyes in the sky' have been used to patrol our beaches. Surf Live Saving Australia, one of the largest water rescue organisations in the world have been early adopters of this technology. This introduction is in addition to the suite of other technology including helicopters, watercraft, closed-circuit cameras linked with communication centres. The revolution in aviation is the result of highly integrated avionic systems and aeronautical processes.[1] Elsewhere UAVs could be providing early-warning intelligence for emergencies such as bushfires and floods[2] or used by ecologists and scientists as conservation drones to monitor land-use changes and other drivers of biodiversity loss and greenhouse gas emissions, species distribution and carbon stocks.[3] In agriculture, 'precision viticulture' are being assisted by UAVs to collect data about a vineyard from sunny spots to soil humidity. When combined with global position system data and geographical information systems, the precise maps provides the vigneron with watering cycles, application of fertilisers and other processes to maximise wine productivity.[4]

> The relative absence or exception to policy from stringent air safety regulation makes the small UAV an attractive platform for users and manufacturers alike

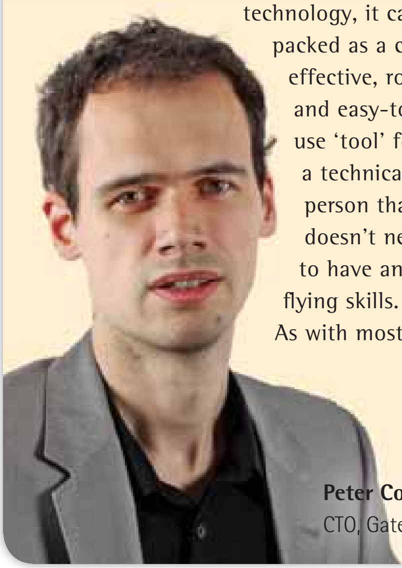
Around the world's sporting arenas there have been attempts to introduce UAVs to enhance the viewing public's experience. At the recent London Olympics, trackside cameras on rails have followed the athletes in the last 200 m of their sprint to capture the excitement and closeness of the contest especially at the finish line. Other technology such as 'spider cams' have been introduced in stadiums everywhere to capture the action either by following an identified player on the field or the ball. But these cameras are 'tethered' on guy cables and directionally fixed and have a limited range of functions. It would be a much better experience if one could follow the cricket ball from behind a bowler's arm or the batsman's shoulder to give viewers that scintillating experience of either a wicket or a six. Television producers attempted to introduce the use of a pilotless helicopter in a recent Twenty20 Big Bash League cricket match in Perth. However, the attempt was abandoned because the producers could not obtain permission from the Australian Civil Aviation Safety Authority because of safety concerns.[5]

UAVs are enigmatic. There is a need to understand the technology and its future is highly dependent on the size, scale and function of the UAV. Whether these are characterised as helpful drones in a disaster or a killer drone will depend on policy, regulation and its legal uses. In this paper we only examine one aspect, how to define and describe the PAV.

Slow adoption of regulations that allow for easy operation is the principal growth limiter for the industry

UAV technology gives access to a massive amount of applications that will change our lives. A fundamental aspect of it is the fact that UAVs can be automated to a very high degree, even to the point that it essentially becomes a flying robot programmed for its task and with user interaction limited to remote actions for (safety) back-up only. This aspect has driven military ISR-applications (intelligence, surveillance an reconnaissance), mainly those that are commonly called D3 applications (dangerous, dull and dirty). The detailed geospatial information a UAV can provide (equipped with appropriate sensors) as well as potential cost savings are slowly but steadily making it a useful system in civil and commercial applications. Remote sensing is expected to be the main application category but there are others as well such as spraying (crops and forest fires), transportation and its potential use as a communication relay station.

Gatewing (A Trimble Company) focuses on just a small part of the remote sensing applications, in particular those for geospatial mapping and surveying. Due to the fact that the task is well-defined prior to the flight, this allows for a high degree of automation, and due to the scalability of the sensor and the UAV technology, it can be packed as a cost-effective, robust and easy-to-use 'tool' for a technical person that doesn't need to have any flying skills. As with most solutions based on remote sensing UAVs, it comes with software that is capable of transforming the sensor data in a useful data product for the user. Although the market for Gatewing is small compared to the total UAV market, it certainly is a significant market. In the long run, it will open a market for multiple application-tuned tools that offer quality data products with a clear TCO (total cost of ownership) for a specific business.



Peter Cosyn
CTO, Gatewing

> Drafting the rules has taken up an enormous amount of time (not only in the US), mainly because of the fact that the safety risks are not well understood

Slow set-up and adoption of regulations that allow for easy operation and commercial flights is the principal growth limiter for the industry. This is especially the case in the US (the biggest market for most applications) where no flights are allowed and even approval for flight testing in the NAS (national airspace) is very difficult to obtain. The main reason is the fact that the FAA (Federal Aviation Administration) closed the airspace for all civil and commercial applications in 2003 (when the commercial and civil market was still in its infancy) in an effort to mitigate safety risks as no rules on proper evaluation and use of UAVs where available at that time. Drafting the rules has taken up an enormous amount of time (not only in the US), mainly because of the fact that the safety risks are not well understood and are expected to vary in a broad spectrum depending on the size, speed and material content of an UAV, as well as its specific tasks and actions. It is actual a 'chicken or the egg' problem: viable and safe business cases are difficult to proof if there is no opportunity to fly and sell the system or service on a small scale. In parallel, lobby groups with a different agenda, such as pilot organization that fear jobs (although the pilot definitely is considered a target group for companies looking for skilled UAV operators in less straight-forward missions), have their say in the process. The media is not always helping either as they sometimes zoom in on the cowboys (the guys that defy the rules and fly irresponsibly) and as they continue to talk about military UAVs and their civil counterparts in one ‹breath›, typically using archaic words with a very negative connotation such as the word ‹drone›. Small scale solutions with limited risks and straight-forward missions, such as the Gatewing X100, offer a way forward in many countries and are becoming the market push for UAV technology ... except in the US.

A country that has shown the way forward in Europe and is also a big guide in Europe's effort to harmonize the rules between the nations is the UK. Their process is established for some years now: they have a setup to qualify systems and operators and, although it still is a bit cumbersome, this is enough to build a market with all protagonists involved: organizations that help the government qualifying manufacturers and operators, training centers, service providers, insurers and - of course - end-customers. A year ago there were already more than 100 companies registered that do UAV operations commercially in the UK. A second example is Japan, a densely populated country but with a history of commercial UAV operations. Since the year 2000, a few thousand Yamaha R-Max helicopters have been used for rice spraying.

Definitions

Pilotless aerial vehicles (PAV) have acquired various monikers including 'drones', 'unmanned aerial vehicle' (UAV), 'pilotless aircraft', 'uninhabited aircraft', and mini-satellite or small satellite. For present purposes the term pilotless aerial vehicles, drones, UAVs is used interchangeably to mean one and the same –the aircraft itself. Sometimes more specific reference will be made to distinguish different categories of pilotless aerial vehicles according to particular characteristics such as size, shape, form, speed, mass and other attributes. The general term unmanned aerial systems (UAS) will refer to the totality of the operations where the UAV is but one item.

Drones, while unmanned, are not unpiloted. Ground support from a distance is required to assist in navigation and general flight. Technically drones are not supposed to be re-used, but re-use has become commonplace as these vehicles are now designed to return to base unless they have been intercepted, damaged or destroyed in some way. Drones were so named because they have no 'mind' of their own – a robot with no autonomous decision-making capabilities. However, modern UAVs are more sophisticated with the ability to optimise flight paths, control speed, multitask, and carry various navigation and surveillance platforms and weapons. These types have become known as UCAV – unmanned combat aerial vehicles. Even so, 'attack' drones do not have the independence to identify targets nor launch weapons; these are tasks that are left to human operators back at base some distance away.[6]

Reusable aircraft with the help of human operators from a distance have been in existence as early as World War I where U.S. developers built and tested the first robot attack plane – the Curtiss-Sperry Flying Bomb for example. Pilotless missiles were also a feature of the V1 Flying bombs or doodlebugs of WW II.[7] With the miniaturisation of electronics, light weight digital cameras and other sensors have been built into UAVs giving them an extended range of functions. These UAVs integrate global navigation satellite systems (GNSS) with inertial navigation and other equipment. With the maturation of these autonomous systems through micro-electromechanical system development it is predicted that there will be a growing market especially for those services that offer photogrammetric images of the natural environment, the safe inspection of tall structures, its general use in surveillance and other applications. It has been estimated that the global military drone market alone is close to US$5.9 billion in 2012.[8] But the question is whether the predicted developments will take place in the civilian market without the requisite policy, regulatory and industry support mechanisms in place. There is a need to explore these possibilities.

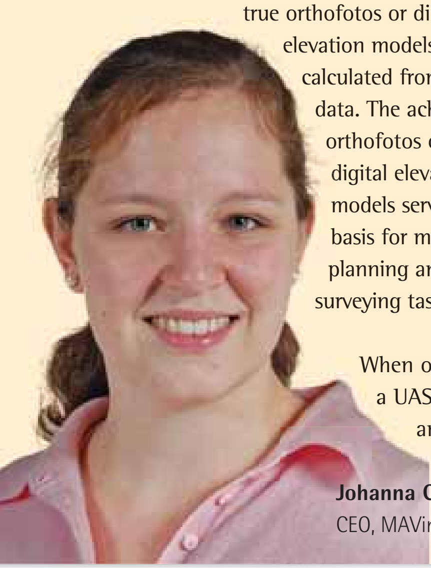
While high levels of skill and inventiveness might be required in supporting UAS, there have been policy and regulatory constraints to the more rapid development and evolution of the UAV industry. In

UAVs have already majored to a professional surveying tool

Unmanned Aerial Systems (UAS) are increasingly used in the geo and mapping sector as an alternative to traditional surveying methods. They are a major asset for many surveying applications because of their advantages compared to traditional surveying methods. These new tools convince in cost efficiency, flexibility and data quality. For some applications such as volume measurement UAS even fill gaps that traditional methods cannot address with acceptable effort.

> Probably the two biggest challenges for the UAS market in future will be to deal with upcoming airspace regulations and to increase the visability of civil UAS applications in the public opinion on UAS

For surveying applications small unmanned airplanes or multicopter type UAS take aerial images of the area of interest. After the flight true orthofotos or digital elevation models are calculated from the data. The achieved orthofotos or digital elevation models serve as a basis for mapping, planning and other surveying tasks.



When operating a UAS, winds and thermal effects can easily produce oblique views in the order of several degrees. These tilted images are a problem for traditional photogrammetry software but due to recent developments in computervision technology new post processing software solutions (such as Photoscan Pro by Agisoft and the Pix4UAV software by Pix4D) exist that are insensitive to highly tilted images. The camera's orientation is reconstructed from the image data itself with high accuracy so the accuracy of the MEMS based IMU is not the limit of the overall accuracy of the final product.

The main advantage of fixed wing UAS compared to helicopter type systems are longer flight times. Therefore the area covered by a fixed wing UAS typically lies in the order of a few square kilometers. While multirotor UAS typically focus on small urban areas or buildings the applications of fixed wing UAS mostly lie outside of urban areas and even in remote areas with little to no infrastructure. Another clear advantage is the higher payload capacity of the fixed wing type airframes. This enables the system to carry a more advanced camera, which takes high quality images.

The UAS market is clearly a fast growing and innovative market. Probably the two biggest challenges for the UAS market in future will be to deal with upcoming airspace regulations and to increase the visability of civil UAS applications in the public opinion on UAS.

From our point of view as a manufacturer of UAS for surveying applications this emerging technology does not only provide a cost-efficient method of collecting 3D data but it also enables totally new applications. The MAVinci technology has proven its cost effectiveness in various projects. The high degree of innovation in the UAS market results in simple products that are no more difficult to use than other traditional surveying equipment. Despite their toy-like appeal UAVs have already majored to a professional surveying tool that can compete with traditional surveying methods.

Johanna Claussen
CEO, MAVinci

a later section this paper examines what these are and how these may act as barriers that may work to impede UAS development. Much of the operational standards and legislative requirements are as yet unarticulated, remain fuzzy in concept and implementation, and have no comparative international benchmarks.

In terms of nomenclature in common use, a comparison of the different types of small satellites and UAVs is summarised in Table 1 below. The terminology used may already have introduced some confusion. For present purposes the simpler reference to micro- and mini-UAVs is preferred. The reason is that when the so-called military drones or the remotely piloted aerial (RPA) systems are brought into the equation the order of magnitude become very large. Military drones are much bigger in size, have an enlarged scale of operations, carry heavier payloads, and travel at higher speeds. This up-scaling of the vehicles suggests that the term 'satellite' might be in order whilst at the same time accommodating the small- to nano-scale vehicle types.

Some observations

Table 1 portrays the diversity and differences in the nomenclature in current use as a rudimentary classification system for UAS. The first observation from the table is the reference to the term satellites and also to small aircraft and light UAVs. These are further distinguished as to whether they are micro- or mini-satellites. Generally, the distinction is that of mass of the vehicle and its deployment. Micro- and mini-satellites or UAVs are the smallest of the vehicles and generally fly below 300 m. Designs have focussed on creating UAVs that can operate in urban canyons or inside buildings, flying along hallways, carrying listening and recording devices, transmitters, or miniature TV cameras. If nothing, else the diminutive size provides vast opportunities and applications in the civilian sphere. The U.S. Defense

Advanced Research Projects Agency (DARPA) criteria for micro UAVs include a size of less than 15 cm, a mass of 100 g or less, a payload of 100 g, a range of 1-10 km, endurance of 60 mins at an altitude of less than 150 m flying at 15 m/s.[9]

A second observation from the table is that where the mass of the vehicle is less than 150 kg their use and operations are governed by local and national regulations. This is because these types of vehicles are considered to be in the 'model aircraft' class of vehicles in the U.K., U.S., and Australia and hence may not require certification standards similar to those of manned aircraft.

A third observation is that tactical UAVs that include special task UAVs and strategic UAVs. Tactical UAVs are heavier platforms of up to 1,500 kg with six sub-categories depending on the range, altitude and endurance. A sub-class is that of the lethal and decoy UAV that weighs up to 250 kg that are used for special military operations. In general, there is a lack of satellite communication systems because of weight and payload restrictions and hence place limits on the distance and range these aircraft can operate. An example is the medium altitude long-range endurance (MALE) UAV known as the MQ-1B Predator. The MQ-1B Predator has sensors in its bulbous nose cones, on-board colour and black and white TV cameras, image intensifiers, radar, infra-red imagery for low light conditions, lasers for targeting and armed with laser-guided missiles. With a cruising speed of between 135-217 kph, a payload of 204 kg and two Hellfire missiles the cost of maintaining such a system has been estimated at $20 m.[10]

Strategic UAVs, on the other hand, operate at higher altitudes; have heavier platforms with longer range and endurance. High altitude long-range endurance (HALE) can weigh between 2,500 – 12,500 kg with a maximum flight altitude of about 20,000 m. These UAVs are highly automated and ground control station monitoring at all times. The famed Northrop Grumman UAV Global Hawk boasts an endurance of 35 hours. There are also non-military HALE such as the solar powered Helios from Aerovironment operated by NASA for Earth Observation (EO) missions

Table 1. Small satellites and UAVs: Classification table

Weight classification group	Civil category	Wet mass (incl. fuel) kg	Regulation	Broad Military Equivalent	Notes and Systems
1	Molecular / femto satellites molesat	0.001 – 0.1	?	?	Launched to fly in an asterism pattern, known collectively as a constellation
1	Pico satellites picosat	0.1 – 1.0	?	?	Fly in formation as a swarm from mother satellite Black Widow MicroStar
1	Nano satellites nanosat	1 - 10	?	?	?
1	Small aircraft	0 - 20	National CAA	Micro (<20 kg) Mini (<30 kg)	?
2	Light UAV	>20 - <150	Civil	Tactical UAV Close range	Phantom, Mikado
2	Micro – small satellites	>10 - <100	Civil	Tactical UAV Short range (<200 kg)	Luna, Silver Fox, Firebird, Photo, Goldeneye
3	UAV	>150	EASA	Tactical UAV	
3	Mini – small satellites	>150 - <500	?	Short range (<200 kg) Medium range (150-500 kg)	Hunter, Aerostar, Sniper, Falco
3?	Special Task UAVs	250 250	Military	Lethal Decoys	MALI, Harpy, Lark, Marula Flyrt, MALD, Nulka, ITALD
4?	Tactical UAV	500 – 1,500	Military	Endurance range	Aerosonde, Vulture II Exp
4?	Tactical UAV	1,000 – 1,500	Military	Medium altitude long range MALE	Skyforce, Hermes 1500, Heron TP
4?	Strategic UAVs	2,500 – 12,500	Military	High altitude long endurance HALE	Global Hawk, Raptor, Condor, Theseus

Notes: ? = unknown or indeterminate; CAA Civil Aviation Authority (U.K.), EASA European Aviation Safety Agency (E.U.)

Sources: Satellite classification: http://centaur.sstl.co.uk/SSHP/sshp_classify.html accessed 24/9/2012 and European Unmanned Vehicle Systems Association (EuroUVS) (2006) *UAV System Producers and Models: All UAV Systems Referenced.* Paris: EUVS.

such as for communication purposes, mapping and atmospheric monitoring.

Fourth, one class of UAV that is seldom featured in discussions are vertical take-off and landing (VTOL) vehicles. These are rotary wing vehicles with a range of weights and configurations. These VTOL UAVs are capable of hovering over specific sites and fly at low altitudes in urban areas. There are both civil and commercial applications such as surveillance and reconnaissance.

In general the smallest class of UAVs are used for civil applications while strategic UAVs are the largest and mostly used in military missions. Cost is a major consideration. For example the MQ-1B Predator's operational parameters may rule out its deployment for civilian use given that other more economic solutions may be available. Also the classification scheme depicted on Table 1 uses mass as a surrogate measure so as to place these vehicles in some order of magnitude. In theory and practice, a more accurate classification schema is to calculate the kinetic energy impact levels of UAVs. This index is easily calculated for any aircraft and may be used as a criterion to classify aerial vehicles.

Preliminary Conclusions

The general impression is that there is an increasing need among industry groups, private users and researchers to use UAVs for their own purposes. The relative absence or exception to policy from stringent air safety regulation makes the small UAV an attractive platform for users and manufacturers alike. Whether this hypothesis is sustainable is yet to be tested. However, this observation alone suggests the pressing need to clarify the policy, regulatory and collateral issues including personal privacy before the industry is to develop further. In addition, there may be significant ethical issues arising from the military as against civilian uses of the technology. From a safety

Civil aviation authorities have started to legalize the use of drones for commercial applications

Recent advances in technology such as very light sensors (GPS, barometers, gyroscopes, etc.) and small but powerful processors & equipment (batteries, cameras, etc.) have opened the door to the development of easy-to-use, small and lightweight autonomous flying systems. This new generation of drones is beginning to conquer the civilian market, especially for GIS, mapping and surveying applications. Indeed, the sky offers new perspectives: small & lightweight drones allow operators to safely capture data anywhere and any time without complex procedures or long preparation time. Small drones are primarily used in the civilian market to produce videos or pictures. In the case of pictures, each image can be linked to a position thanks to the onboard GPS. Images with sufficient overlap can be processed to obtain a geo-referenced Othomosaic and Digital Elevation Model (DEM), thus delivering direct input for environmental planning, construction and mining-related activities.

Why is this new technology so relevant for private companies or public agencies?

In this time of economic crisis cost reduction and high efficiency are key. There are many operational benefits to the use of small drones for high precision mapping and surveying:

Cost reduction: When compared to manned aircraft, the return on investment of a small drone system for mapping of areas of up to 10km² occurs in general already after the third flight. Cost reduction is therefore tremendous.

Increased efficiency: Compared to traditional ground surveying, a drone mapping mission is very time-efficient. For example, an area of 1m² with an Orthomosaic precision of under 10cm can be accomplished in around 30 minutes.

Improved on-site safety: A drone is a remote surveying system and therefore can be operated at safe distance from any dangerous working areas (construction, mining, quarries, or polluted sites). This is especially true for small and very lightweight drones as they present a low risk for third parties in case of system failure.

Beside those operational benefits, small drones have environmental benefits too: they are eco-friendly (usually electric-powered) and are very quiet in comparison to aircrafts. As they are simple to operate, quick to deploy and affordable, they have become accessible even for small businesses and NGOs thus allowing data gathering for sustainability projects (agribusiness, reforestation) or disaster management.

How do the different aviation authorities regulate the use of drones?

Civil aviation authorities around the world have started to legalize the use of drones for commercial applications and are working on related regulation standards. UK, Australia, Canada, France, Germany, Switzerland among others have already implemented dedicated rules to regulate VLOS (Visual line of sight) and even exceptionally BLOS (Beyond line of sight) operation of drones. Other countries (US, Brazil, South Africa among others) are still working on the definition and implementation of standards. Existing regulation standards can include the need for an airworthiness certificate for the drone (often dependent on a weight criteria), a permit to fly in a certain area (often dependent on mission scenarios) or a license for the operator.

Andrea Hildebrand
Co-founder, senseFly

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The greatest challenge is acceptance by the aviation fraternity

The applications for UAV/UAS technology are many, and the benefits are already being realised around the world. With a high degree of stability and a high resolution sensor we are employing the technology in the mining, construction, engineering and survey industries. A common factor among these environments is the safety culture and in particular the site safety requirements. An area where the UAV shines is its ability to service these sites without putting the operators in harm's way. The UAV allows the team to stand off and perform the task without entering the mine or worksite, as the case may be, and therefore reduces the risk to the individuals and the safety burden to the operating company. There is much potential yet for new and exciting applications of this technology. As airborne sensors becomes smaller and more affordable, specialised acquisition which had previously only been the domain of manned aviation domain will inevitably become part of the UAV/UAS toolbox. These may include multi and hyperspectral cameras, thermal video, air quality and gas sniffers to name a few. With the advent of hydrogen fuel cell technology, the potential for extremely long endurance from UAV/UAS systems draws steadily closer.

One of the challenges to the UAV/UAS industry is to allay the public fear that all of these types of aircraft are "spy drones" and their privacy will potentially be impacted each time one flies. Spreading the word that photogrammetry or mapping UAVs pose no threat in this regard is the key here. But perhaps the greatest challenge for UAV operators is acceptance by the aviation fraternity. We refer firstly to the pilot community, who view the saturation of their airspace with unmanned aircraft with much trepidation, worrying about separation and avoidance with potentially unsafe vehicles sometimes too small to see. Secondly and very importantly we refer to the aviation legislators and airspace management, the likes of the FAA in the United States and CASA in Australia. These organisations maintain oversight of the operation of all significant powered aircraft and demand that minimum standards are met. It is our belief at Hawkeye UAV that no commercial UAV should be operated outside the law, and as such we have always postured ourselves to seek approval for our business practises, documentation, procedures and aligned our operations with the governing body responsible for each country. We are aviators ourselves and recognise the risk inherent with UAV flying so the importance of authorisation not only protects us and our clients, but enables us to be insured for our operations. It begs the question, should UAV operators undergo training and should proof of training be required if asked for by authorities? Longevity of the equipment is an inevitable challenge as UAVs have entered their commercial life and begun to amass flying hours. How long should each reasonably be expected to last? The equipment is often expensive and with many aircraft types employing a controlled-crash or belly landing recovery method, the lightweight airframes suffer a lot of stress. With traditional aircraft there are extensive maintenance schedules and inspection regimes. Should an unmanned aircraft be any different?

Simon Morris
GIS Manager, Hawkeye

point of view, the integration of the use of such vehicles from the segregated military airspace to the more general civilian airspace may require the development of some form of a shared 'open' skies policy. Industrial uses and developers of such systems may also require certainty with rules and regulations, interoperability of equipment in different jurisdictions and a market that may be sustained and large enough to pay dividends for the investments in research and development. In this respect there is as yet an internationally agreed classification system for UAS.

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UAV project - Building a reality-based 3D model

In this paper, the UAV mission and the data processing steps to generate a 3D model of the NUS (National University of Singapore) campus have been described

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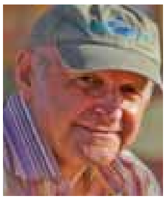

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Nowadays researchers and various users are very interested in urban applications at large scale, where small UAVs are very useful. In Photogrammetry, UAVs represent a very flexible and low-cost platform which reduces data acquisition time and provides for high resolution and high accuracy data for small area modeling. Currently, there are increasing demands on urban applications such as environment monitoring, accurate DTM for flood simulation and highly accurate building modeling for architectural usage (Gruen, 2012). In this paper, we report about a pilot project of using UAV technology to build high resolution urban models at large scale. We performed this mission in a quite complex urban area in the tropical city of Singapore with a Falcon 8 octocopter, developed by Ascending Technologies GmbH, with an off-the-shelf camera Sony Nex-5.

Most of the UAV applications are performed in suburban or rural areas, such as cultural heritage sites (Eisenbeiss et al., 2005, Remondino et al., 2009), suburban mapping, and agriculture monitoring (Lin, 2008; Gruen, 2012), in which the take-off and landing places are quite controllable. However, little work is reported about mapping urban areas with UAVs. On one hand, it is hard to control the landing and take-off in urban areas, on the other hand, the regulations of air control or even police/military are quite strict for drones flying over important facilities, infrastructures, pedestrians, since safety is the most important concern for air regulations. Our flight mission was approved after a 6-months period of evaluation. However the flying height was restricted to 150 meters. This produced 857 images with very complex scenes and large parallaxes between images. Moreover, the mission had to be divided into multiple flights because of the poor battery capability and limited operating distance of the UAV, which results in gaps and irregular overlap on the borders of each flight. Geo-referencing these images with a complex geometry turned out to be a challenging work.

In this paper, we report about the difficulties encountered in the data acquisition stage, including various aspects of flight planning, selection of take-off and landing positions, data pre-processing, triangulation, bundle adjustment, 3D modeling, and then introduce our solutions to solve for these steps. In summary, our contribution in this paper is three-fold: 1.We describe the advantages of using UAVs as a mapping and modeling tools for large scale urban mapping and modeling, and list the potential problems and solutions in the practical work, 2. We compare the performances of different commercial and non-commercial software packages in geo-referencing high resolution UAV imagery with large parallaxes and slightly unconventional network structures 3. We analyze the drawbacks of the chosen methods in the mission and provide suggestions for smoother procedures in UAV modeling in dense urban areas.

Data acquisition and data cleaning

The modeling area covers the main campus of National University of Singapore of approximately 2.2. This may not be a large area in mapping, but considering the flying height of 150

Figure 1: The NUS mapping area. Different colors show different area separated by roads.

meters and a camera constant of 16 mm with an off-the-shelf camera, we obtained 857 images in total. There is another restriction concerning the flight: the octocopter is not allowed to fly across the major public roads and should stay strictly within the campus boundaries, which splits the whole area into 3 parts (Figure 1). This required the flight path to follow the border of the campus closely.

The AscTec Falcon 8 is used for the mission. It is a two-beam octocopter with 4 rotors on each side, powered by battery. It has a build-in GPS/IMU, a barometer, electronic compass and a stabilizing system for both the camera and the platform. It has up to 300 meters remote controlling distance with a maximal operation slot of 20 minutes. Comparing to fixed-wing platforms, it has several advantages:

1. It does not need a runway or ejection devices.
2. The take-off and landing space can be relatively small and confined.
3. The mission can be terminated directly when unexpected situations happen, such as strong wind, unexpected rain or the approaching of another flying object.
4. Image acquisition can be done in a discrete mode by hovering when taking images, which can reduce the motion blur during the operation.

However, since the octocopter needs more power to keep operating, one of the biggest disadvantages is the short operation time. In ideal conditions with a flying height of 150 meters, the octocopter can take 6 images with a baseline of 50 (80% overlap) meters in strip direction and 5 strips with a baseline of 65 meters across strip direction (60% overlap) in one flight, in total 30 images. However, due to signal disturbance and unexpected circumstances like strong wind, loss of connection, etc. we only took maximal 25 images per flight for safety reasons, sometimes even less, especially when the flight approaches the boundaries of the mapping area.

Take-off and landing

During the practical operation take-off and landing are the most demanding issues. The ideal situation for take-off and landing is on the roofs of houses, if relatively large and open spaces are available (is suggested). However, most of the roofs are not accessible. Since Singapore is a typical tropical country, and there are a lot of complex cooling systems on the roofs, the spaces on roofs are quite confined. In this case, the take-off and landing spaces are mostly restricted to the ground: pedestrian ways, playgrounds, parking lots, etc. (Figure 2). During the take-off and landing, the biggest challenge is to avoid large tropical plant canopies. Therefore we used the manual mode for take-off and landing for a more flexible performance, and then switched to automatic waypoint mode after the octocopter rose to a certain height.

Electro-magnetic disturbance

Due to the complex infrastructures with different functionalities in urban areas, which may create electro-magnetic disturbances, the loss of signal happens quite often. In this case, the pilot needs to move around for an appropriate angle and distance to get the signal back. Therefore, it is suggested to perform the operation early in the morning, when less human activity and radio disturbances are involved. Our data acquisition took 3 days of field work, consisting of 43 independent flights.

Ideally, the produced images and GPS/IMU records should match perfectly, but our actual data contained a fairly amount of deviations, which can be divided into two types: 1. The GPS/IMU values do not match the images; 2. More images are taken automatically beyond the planned numbers. Those problems may come from the electro-magnetic disturbances which misguide the remotely controlled signals, or bugs in the system software. Therefore, data cleaning took quite some time. We wrote some scripts to accelerate the process by checking image overlaps, deleting images with too much overlap, getting rid of repeatedly taken images, and detecting GPS points which deviated too much from the mean position of the block. Data cleaning finally resulted in 857 images out of 929 raw images with corresponding GPS/IMU records, which are shown in Figure 4.

GEO-Referencing

Camera and calibration

The Sony Nex-5 is a mirrorless interchangeable-lens camera, with an image dimension of and a pixel size of in both x and y directions. We use its

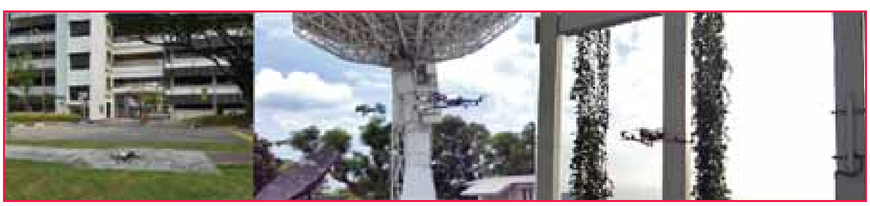

Figure 2: Examples of take-off and landing in confined urban areas

Figure 3: Blur in image corners of Sony Nex-5

original lens with a fixed focal length of 16 mm. However, the focusing cannot be fixed and it will automatically focus for each single shot. This camera is well commented in photography, but as we found, the lens has a fair amount of colour refraction, leading to blurring problems in the image corners (see Figure 3).

The camera calibration was done in our lab with the software package I-Witness, using the point cloud calibration method (Remondino, Fraser, 2006). The process of camera calibration is fully automatic. After calibration a re-projection error of 0.24 pixels is obtained.

Geo-referencing

Our geo-referencing process was divided into two stages: 1. Test the triangulation and bundle adjustment with a small subset of all images of this mission. We took the images from one flight as a small subset. To include more GCPs for the test we added four more images in the block corner (Figure 4, highlighted in yellow), 2. Try to do the geo-referencing of the full block with different software packages according to their performance in the small block. The small block tests were performed because it is easier to analyze data in a small dataset. We assumed that if a software package will fail with the small block it will inevitably also fail with the full block. For the full block, we acquired 39 control points with Trimble GPS, with an accuracy of 2 cm in x, y direction, and 3 cm in height. The distribution of the GCPs is shown in Figure 4. In the small block triangulation, points 18,19,20,21 are used as GCPs and the others are used as check points.

We also used the small block for an accuracy analysis of the measured exterior orientation parameters. For this purpose we compared the GPS/IMU measured values with the results from bundle adjustment, which were considered the correct values. Table 1 gives the results of this analysis. We can see that the positional values, as determined by GPS, have maximal values at 4.7, 9.1, 3.2 m for X,Y,Z. But they include a large bias (shift), which, if removed, gives coordinate accuracies for X, Y, Z of about 1 m. The attitude values have maximal deviations of 12.9, 9.2, 3.1 deg for roll, pitch, yaw, and the removal of a shift bias will improve the standard deviations to 3.8, 5.6, 0.8 deg.

The control points are denser in the northern part of the mapping area, which results from the triangulation and bundle adjustment tests for the small block, and those points are then

Table 1. Small block accuracy analysis of navigation data. The measured exterior orientation parameters are compared with those from bundle adjustment

	X(meters)	Y(meters)	Z(meters)	Omega(deg)	Phi(deg)	Kappa(deg)
Image 1	-3.16	-7.48	-2.39	1.46	1.59	0.77
Image 2	-2.67	-8.55	-2.13	-5.31	-6.28	-1.45
Image 3	-4.17	-4.17	1.69	1.69	8.24	1.61
Image 4	-4.75	-4.47	1.48	1.82	9.23	1.49
Image 5	-2.65	-7.94	-3.39	-7.01	2.04	1.69
Image 6	-1.50	-7.83	-2.76	-4.56	-3.45	1.29
Image 7	-1.37	-7.57	-2.68	-4.28	-3.75	-0.14
Image 8	-1.11	-7.88	-2.89	-4.13	-4.59	0.24
Image 9	-1.26	-7.83	-2.55	-5.01	-5.03	0.63
Image 10	-2.73	-9.08	-3.24	-11.76	3.19	0.01
Image 11	-2.90	-7.33	-2.64	-1.12	7.31	1.07
Image 12	-2.66	-7.14	-2.01	-1.84	7.71	0.70
Image 13	-2.91	-7.38	-2.49	-2.96	6.97	1.03
Image 14	-3.14	-7.09	-2.39	-4.31	7.87	1.46
Image 15	-2.47	-8.03	-2.04	-11.39	3.45	1.58
Image 16	-0.95	-7.00	-1.42	-5.37	-2.12	1.02
Image 17	-0.86	-7.55	-1.15	-6.36	-4.76	1.16
Image 18	-0.86	-8.21	-1.20	-6.67	-4.04	0.77
Image 19	-0.98	-8.20	-0.86	-7.79	-4.93	0.82
Image 20	-2.26	-8.87	-1.65	-12.99	0.78	1.18
Image 21	-3.07	-6.93	-1.16	-3.00	7.67	0.66
Image 22	-2.79	-6.84	-0.93	-3.61	6.85	1.78
Image 23	-3.35	-6.67	-1.09	-5.92	6.34	1.11
Image 24	-3.26	-6.68	-1.84	-2.77	8.25	0.96
Image 25	-2.88	-8.22	-2.00	-12.92	0.62	2.05
Image 26	-1.63	-7.03	-1.65	-6.63	-4.98	3.08
Image 27	-0.95	-7.36	-0.48	-7.47	-4.82	0.57
Image 28	-0.83	-6.84	0.37	-5.90	-6.59	1.33
Image 29	-1.08	-6.46	1.24	-5.96	-5.29	-0.66
mean	-2.25	-7.33	-1.53	-5.24	0.95	0.96
RMSE	2.49	7.41	2.01	6.46	5.63	1.27
Std	1.07	1.05	1.31	3.78	5.55	0.83

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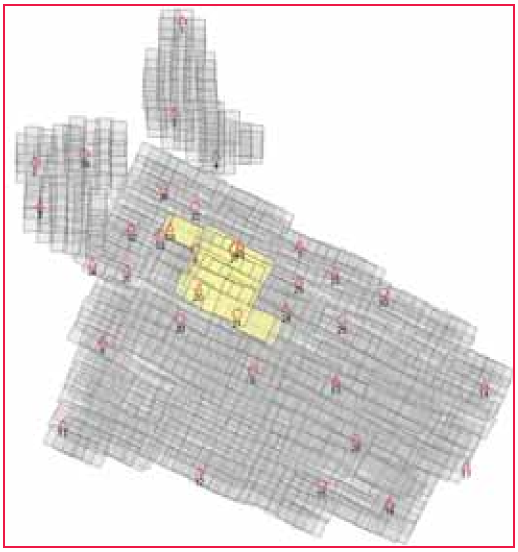

Figure 4: Acquired imagery, control points and check points. Triangle: Control points, circle: Check points. Area highlighted in yellow: Sub-block for geo-referencing test.

also used to perform bundle adjustment in the whole area. The control point distribution for the full block is not ideal, because, due to occlusions by tropical vegetation and other objects, the optimal locations could not be realized. We performed the geo-referencing of the small block with several pieces of commercial and non-commercial software. Most of the software tested in our mission worked relatively well and we obtained an accuracy of about 5 cm in horizontal, and 5-8 cm in vertical direction. However, when it comes to the full block we are running into problems with geo-referencing, which will be shown in the next sections.

Leica Photogrammetry Suite (LPS)

LPS is a popular commercial software package for geo-referencing due to its easy-to-use interface and compatibility with a variety of sensors. This software is not specifically designed for UAV imagery. LPS has two modes of tie point measurement: 1. given an estimation of the exterior orientation parameters, LPS will look for corresponding points along the computed epipolar line by correlation methods; 2. Measurement of 3 or more points per pair manually as seeds, LPS will generate additional tie points from these points.

The first mode depends on the quality of initial exterior orientation parameters. We imported the recorded GPS/IMU data as the initial exterior orientation parameters, but it failed because of the poor quality of this data (compare Table 1). The second mode could be a valid way when the dataset is small, but it is not possible to manually measure the tie points on 857 images. Therefore, we wrote a separate program to generate tie points with the Sift operator features (Lowe, 2004): it first generates Sift features, and looks for neighboring images of each image by the recorded GPS position. Image matching is applied with Sift features in the neighboring images. Finally a Ransac algorithm (Zuliani et al., 2005) based relative orientation is performed to orient all the images for detecting blunders and a LPS-formatted tie point file is output. After the tie points stage, we measured the controls points manually and run the bundle adjustment. We used self-calibration by releasing focal length, principle point and radial distortion. This works well with the small test data set, but it produces unacceptable results for the full dataset. The residuals in check points of the full dataset are shown in Table 2.

Table 2: Result of bundle adjustment of the full block with LPS. Residuals in check points. UAV image footprint ca. 5 cm

Check Pt No.	Max ImRes x (pixel)	Max ImRes y (pixel)	ResX (meter)	ResY (meter)	ResZ (meter)
6	0.76	0.29	0.198	0.176	-0.910
9	1.28	1.19	-0.081	0.142	2.074
10	0.68	0.35	0.303	0.113	4.351
15	0.26	1.03	0.005	0.074	0.347
21	1.74	0.25	-0.040	-0.071	0.202
22	3.27	1.96	-0.193	0.120	1.742
29	0.61	0.88	0.136	0.137	-0.346
30	1.48	1.22	-0.099	-0.089	0.189
31	0.38	1.22	-0.076	-0.071	-0.173
33	1.04	1.22	0.104	-0.116	0.113
39	1.09	0.98	0.125	0.109	0.999
Mean			0.124	0.111	1.041
Std			0.150	0.110	1.474
RMSE			0.147	0.115	1.608

In Table 2 residuals of some of the check points and the standard deviations of the X, Y, Z residuals are very large, especially in height, which indicates a poor geo-referencing. Here are several possible reasons for this: 1. the tie points generated by the Sift operator may not be well distributed, since it can hardly find distinct features on tree canopies, which sometime takes a large portion of the image content, 2. though we had done the blunder detection in our program, small blunders may still exist.

APS (Aerial Photo Survey) from Menci Software

APS is a fully automatic software package in which a fairly small amount of interaction is involved. It is originally designed for images acquired by Swinglet from senseFly, while it can also handle images from other UAV imagery, such as Gatewing, Falcon 8, etc. The software requires as input lat/lon/height/heading/pitch/roll, and if a different exterior orientation system is used, the users need to convert the values externally. However, due to the high automatic workflow, the software provides limited customized settings to adjust the performance of bundle adjustment. In our case it has a fair performance in bundle adjustment in an arbitrary coordinate system, but it does not perform well when GCPs are involved. It leads to a maximal residual of more than

0.5 meters for check points within the small test block. Therefore we only did bundle adjustment of the whole dataset in an arbitrary coordinate system, and finally it succeeded to orient all the images with a re-projection error of about 2 pixels.

MATCH-AT and customized tools from Graz University

INPHO helped us to test the Match-AT module with our dataset. It failed to get the required accuracy.

A customized software package from Graz University, which implicitly uses the method proposed in (Irschara et al., 2010, Maurer et al., 2012) was also tested with the dataset. It can robustly orient the dataset and kick out images which have large re-projection errors. It finally oriented 600 images, with a re-projection error of 1-2 pixels. In its current version the software is not able to incorporate the GCPs into the bundle adjustment.

APERO

APERO is an open source tool developed by the French National Geographic Institute (IGN). It is designed for high-end users with different strategies and various parameter configurations for bundle adjustment. This tool is a command–line based program working under Linux and MacOs. All the parameters and the strategy related to bundle adjustment are specified in a XML file. APERO uses Sift features to extract tie points, and if the matching strategy is not specified, it will start an exhaustive search for neighborhoods. Therefore, for our UAV dataset, we wrote a small script to look for image neighborhoods based on the GPS positions. For each image we defined its neighborhood by a given radius. Images whose distances to this image are less than the given radius will be defined as neighborhood images. Since there are 3 parts which are separated by roads (Figure 1), the radius should be large enough to cover these gaps.

APERO renders quite acceptable results with free-network bundle adjustment, with an average re-projection error of 0.5 pixels. Then the ground control points are introduced to do a final geo-referencing. The result is shown in Table 3.

We can see that after involving the GCPs in the bundle adjustment, we get a maximal residual of 0.15 meters in coordinates (compared to 5 cm footprint). Since we got a very good result in free network bundle adjustment (0.5 pixels), we can exclude measurement problems in tie points. The decrease in accuracy when doing the GCP-oriented block may have several possible reasons: 1. Auto-focusing is not modeled (the camera auto-focuses for each image taken), 2. Multiple flights with different weather conditions during the 3 days period. Shadows moving and varying significantly, 3. The camera lens has some problems as we discussed in 3.1. Those problems will be investigated further in our research.

> In some countries flight permissions are difficult to get. The safety issue is the most essential concern. Besides, restrictions on mapping area boundaries and classified objects create difficulties and irregularities in flight execution.

Object measurement

We use CyberCity Modeler (Gruen, Wang, 1998) to model buildings on the NUS campus. It is a semi-automatic procedure. While the key roof points are measured manually in stereo mode, the software fits the topology automatically. Giving ordered point clouds measured in a Digital Workstation following a set of criteria, it will automatically generate roof faces and wall faces, where only a small amount of post-editing is needed. It greatly reduces the operation time for constructing building models and can generate thousands of buildings with a fairly small work force. It is also invariant to model resolution, and is able to generate finer details on building roofs such as air-condition boxes, water tanks, etc. We used ERDAS StereoAnalyst as Digital Workstation and implemented a converter between StereoAnalyst and CyberCity Modeler.

Since Singapore is a tropical country with a large amount of tree canopy around

Table 3: Result of bundle adjustment of the full block with APERO. Residuals in check points.

Check Pt No.	Max ImRes x (pixel)	Max ImRes y (pixel)	ResX (meter)	ResY (meter)	ResZ (meter)
6	1.89	0.87	0.102	0.066	0.016
9	1.53	0.64	0.004	0.04	0.08
10	1.93	1.46	0.142	0.005	-0.099
15	1.4	1.06	0.142	0.134	-0.014
21	0.74	0.43	-0.009	-0.007	0.006
22	1.98	1.25	0.038	0.057	-0.148
29	1.1	0.53	-0.005	0.039	0.026
30	1.57	0.77	-0.012	-0.024	0.016
31	1.57	0.94	0.05	0.027	-0.026
33	1.6	0.82	0.057	0.052	-0.044
39	2.39	0.79	-0.108	0.122	-0.061
Mean			0.061	0.052	0.049
Std			0.057	0.036	0.048
RMSE			0.080	0.066	0.065

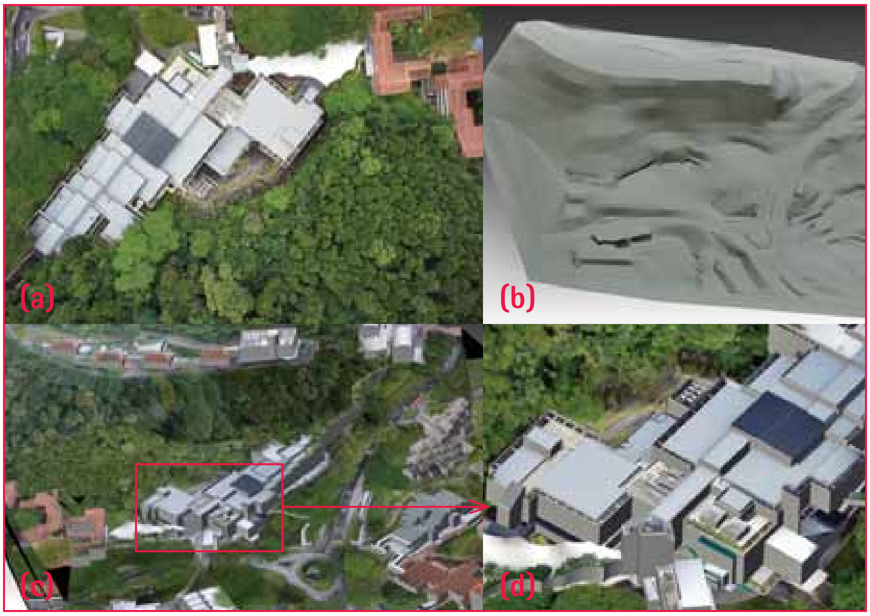

Figure 5: Initial results of NUS campus modeling: (a) one of the UAV images; (b) measured terrain; (c) textured 3D models. (d) zoom-in result.

the city, we face difficulties in DTM measurement, especially with images taken at low altitude. Green plants lead to many occlusions. Therefore, for areas where there are trees the DTM accuracy of those areas cannot be guaranteed. In this scenario, to build an accurate terrain model even under the plant canopy, extra information is needed. We obtained this information by acquiring Lidar point clouds from a mobile mapping system (RIEGL VMX 250), driving around campus. The Lidar points will then be used to assist building a precise terrain model under the trees along the roads. Intermediate results of the building modeling are shown in Figure 5.

Conclusions

In this paper, we have reported about our activities of using an Unmanned Aerial Vehicle to perform 3D modeling in urban areas at very high resolution. We have found that several factors in performing such missions are very important:

- Air control restrictions. In some countries flight permissions are difficult to get. The safety issue is the most essential concern. Besides, restrictions on mapping area boundaries and classified objects create difficulties and irregularities in flight execution. Restrictions on flying height may result in too many images within a small mapping area, which creates more work load and complexity.
- Take-off and landing positions. It will not be a problem when doing mapping

in suburban area, while it is not easy to find suitable places for take-off/ landing in complex urban areas. For this reason the use of fixed wing UAVs can practically be ruled out.

- The choice of UAV should be related to the dimension of the project. A small UAV is flexible, and flight permissions are easier to get. But there are limits in battery capabilities and communication links, which may lead to multiple flights and large work load.
- The radio disturbances in urban areas frequently intervene with the control signal, which results in loss of link during operation. This further produces errors in the downloaded data (mismatch between image and GPS records).

For data processing, some commercial software packages are available with fully automatic workflow for some components of the UAV image analysis process, but most of them are designed for non-expert users who do not have high requirements in result reliability and precision.

In our project we encountered the following problems in UAV acquired imagery:

- Multiple flights. Due to the short life of batteries, and limited flying distance the whole mission had to be divided into several flights (43 in all), which were taken under different weather conditions. This leads to shadow variations (movement of shadows from image to image and intensity changes). Also, the camera kept on auto-focusing during the data acquisition.
- Due to the limited GPS accuracy of the system, the overlap varies a lot, sometimes more, sometimes less, especially at each flight's perimeter.
- The navigation data was of poor quality. In the small block we had errors of the perspective centre coordinates of up to 9 m, in attitude values of up to 12 deg. This causes problems in automated tie point extraction, if the image matching is performed with orientation constraints (which is advisable).
- Poor image quality. The camera Sony Nex-5 has lens problems in the image corners (unsharpness and color seams), which may potentially affect the quality of geo-referencing and post-products.

The above factors could affect the results of bundle adjustment. Finally, and as the best case, we obtained an accuracy of 6-8 cm, computed from check point coordinates, with APERO. This compares quite well with the pixel size of 5 cm.

This project is still ongoing. We will measure and model the whole campus, including trees and textured terrain. If some of the aforementioned problems are solved we can see the potential of using UAVs for creating 3D models of dense urban areas at high resolution. In the future development, the objective must be to generate a smoother workflow for urban applications, with reduced difficulties in data acquisition and processing. Therefore, we are looking for larger platforms with more operation time, and higher flying altitude, which will reduce the number of flights, have less occlusions and also be equipped with a higher quality camera.

Aknowledgements

We acknowledge the help of Menci Software in providing an evaluation license for bundle adjustment testing. We also would like to thank Prof. Bischof and Christof Hoppe for running their bundle adjustment for evaluation and INPHO for testing MATCH-AT with our dataset. We also appreciate the help of Dr. Fabio Remondino in providing suggestions for the APERO processing.

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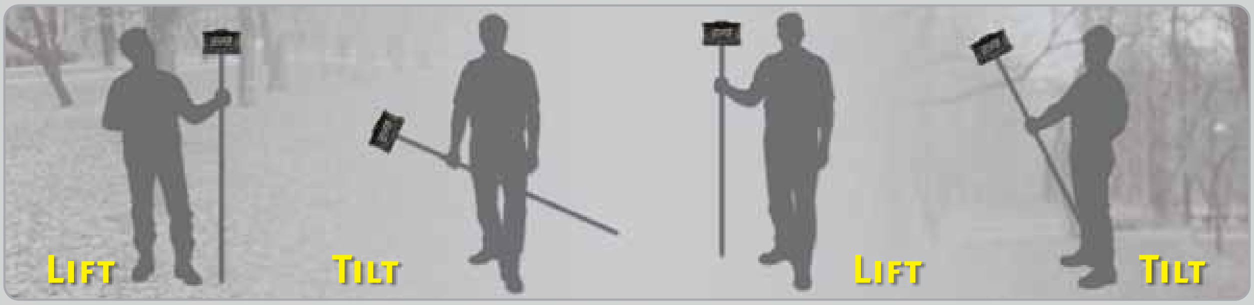

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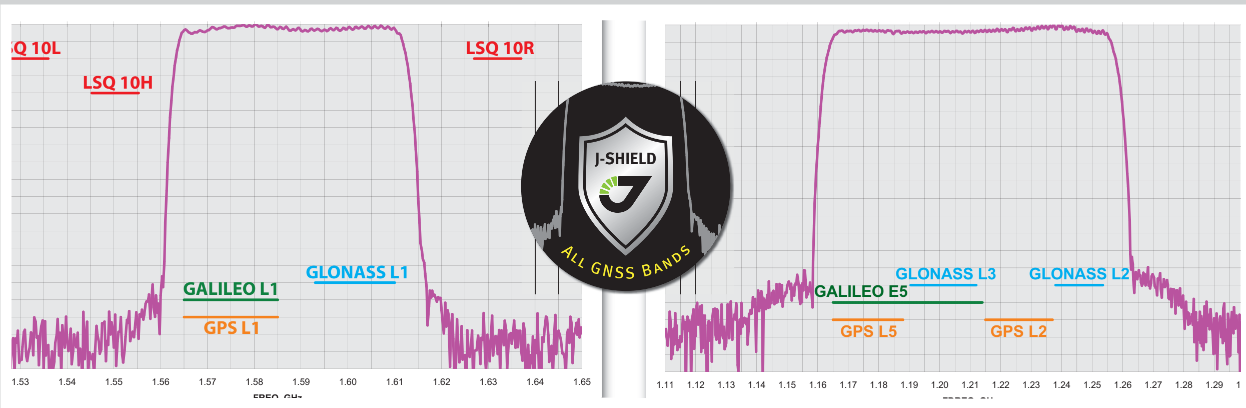

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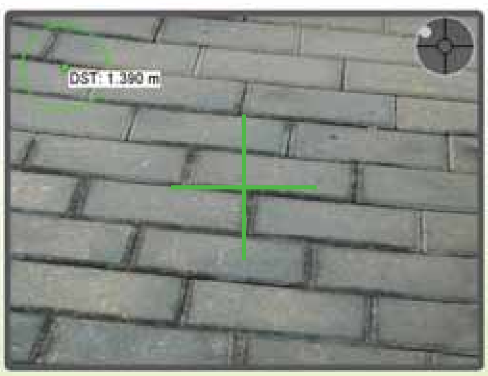

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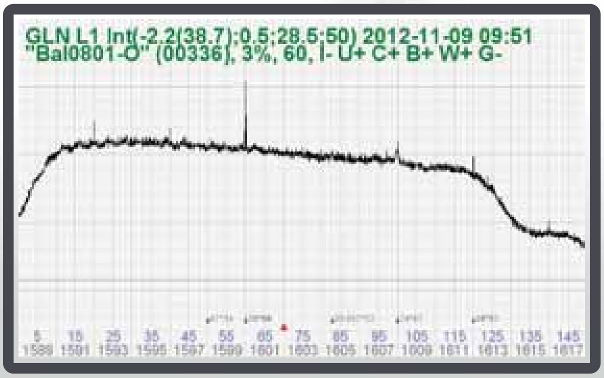
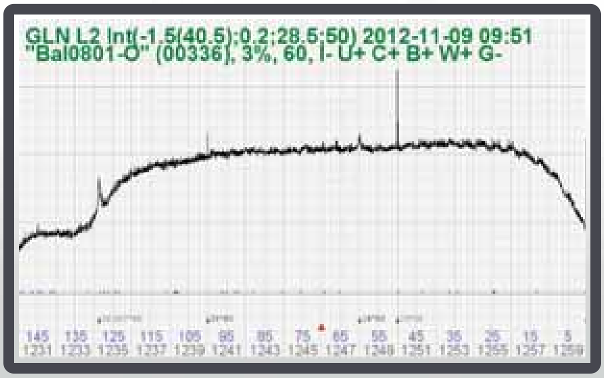
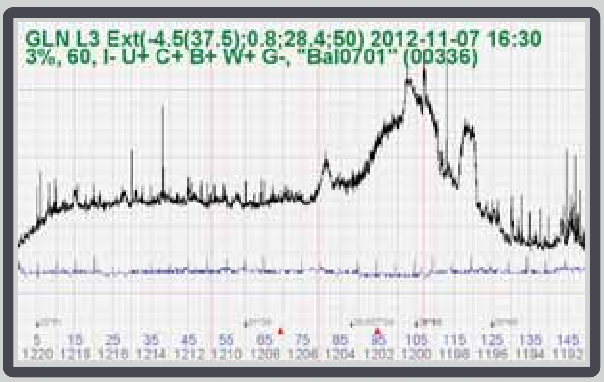
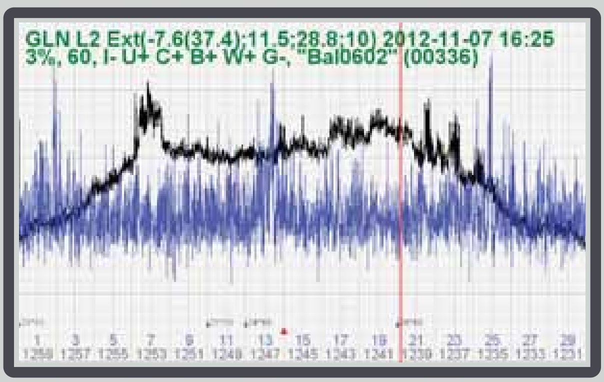




Actual examples of clean GNSS environment





Actual examples of noisy GNSS environments. People could not use these satellites and did not know why.

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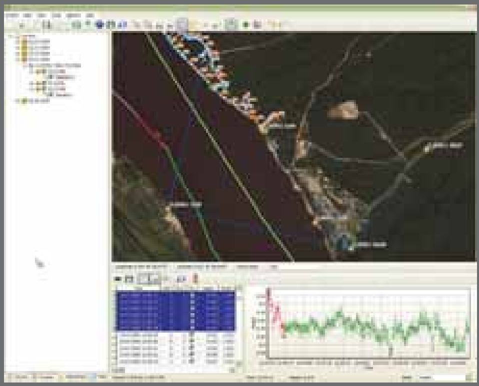

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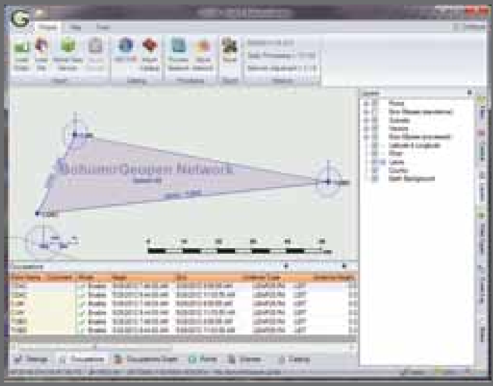

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Smart Solutions for disaster management

Learning from the Great East Japan Tsunami and the Accident at Fukushima NPS

Shunji Murai
Professor Emeritus,
University of Tokyo, Japan

During and after the Great East Japan Earthquake and Tsunami, about 20,000 persons died or are still missing, of which 92.5% were victims of the Tsunami. The fourth biggest earthquake plus Tsunami in history swept away 220,000 houses and 18,000 fishing boats. The control points installed at the sea bottom 130 km offshore near the epicenter showed 24 m horizontal crustal movement to east-east-south and 5 m uplift vertically, while a GPS Station at Ojika, which is located on the coast nearest to the epicenter showed 5.3 m horizontal movement in the same direction and 1.2 m settlement vertically which would be a trigger to generate Tsunami (see Figure 1).

Prediction of earthquakes

Using GPS data provided by Geospatial Information Authority (GSI), Japanese Government, the author's group succeeded to predict earthquakes through the trend analysis of time sequential data. There are about 1,200 GPS Fixed Stations called electronic control points all over Japan as shown in Figure 2. The data derived from these GPS stations can be downloaded free of charge on the Internet.

Figure 3 shows an example of predictions in the case of Great East Japan Earthquake including the critical pre-signals of 5 weeks, 4 weeks and 3 weeks respectively before the earthquake. A symbol x shows the epicenter. The most critical pre-signals were 3 weeks before the earthquake though the signals weakened afterwards until the earthquake occurred. This behavior of the early signals is interesting but the reasons are still unknown. We observed the possible occurrence of an earthquake before the event but we did not alert the public as we had no authority to do so. But now we are permitted to develop a business that will provide a service on earthquake prediction as a commercial activity.

Japan is surrounded by four tectonic plates including the Pacific, Philippines, Eurasian and North American Plates (see Figure 4). Mt. Fiji stands at the junction of Philippines, Eurasian and North American Plates. In the past Mt. Fuji's eruptions were linked to the giant earthquakes. Therefore Japanese are concern about the possibility of the next eruption of Mt. Fuji in near future. We have only one GPS station on the Pacific Plate, which is at Minami Torishima, which did not move much during the Great East Earthquake. Ojika GPS Station nearest to the epicenter showed pre-signals 15 days and 3 days before the earthquake as shown in Figure 5 though the GPS station ceased its operation after the earthquake.

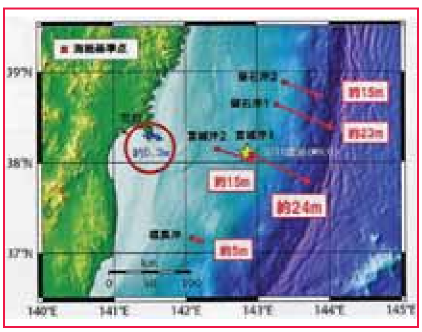

Figure 1: Crustal Movement

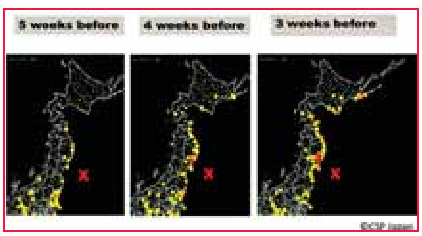

Figure 3: Pre-signals of earthquake with GPS Data

Figure 2: GPS Stations of GSI

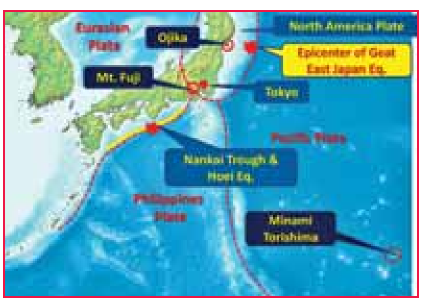

Figure 4: Location of GPS stations of interest

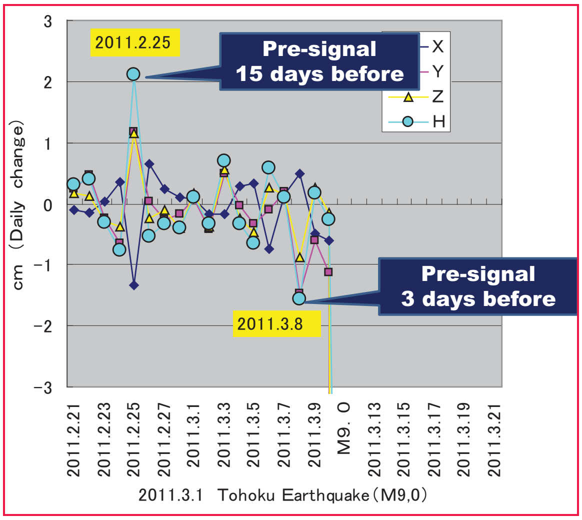

Figure 5: GPS data at Ojika

Early Warning

Early warning is the most difficult task in disaster management. Early warning of the Tsunami had intended to be based on GPS wave height recorder as shown in Figure 6. However, although there were about 15 GPS wave height recorders installed 15 to 20 km offshore along the Pacific coast, there was only one Tsunami GPS wave height recorder located 15 km offshore of Kamaishi City near the epicenter, which could record valuable wave form of the Tsunami. It revealed the first occurrence of a 6.6 m high Tsunami 30 minutes after the earthquake and subsequently a total of seven occurrences up to 6 hours afterwards. This would be the first record of a giant Tsunami in the world (see Figure 7). The Tsunami wave offshore will be increased up to about three times (about 20m) as it crosses the coast depending on the sea bottom topography and will flow inland up to almost 30 to 40 m above the sea level. Though the GPS wave height recorder is useful to record the Tsunami wave forms, it would not work as early warning system because the Tsunami wave will arrive at the coast within about 5 minutes with the velocity of about 100 km per hour. But the Japanese government is attempting to increase the number of GPS wave height recorders offshore in the Pacific Ocean for early warning.

Figure 6: GPS Wave Height Recorder

Preparedness

Preparedness against future earthquakes and Tsunamis are most important in order to avoid a similar catastrophe. Many people tried to escape responsibilities for not preparing for such a disaster by saying that they did not expect such a large Tsunami. Now they cannot avoid being responsible for one of the worst examples of making an incorrect assumption leading to a lack of preparedness. Archaeological excavations have investigated ground layers along the coast lines in Japan to reveal the traces of past giant Tsunamis as shown in Figure 8-1. The Tsunami layers are easily detected from such ground excavations as shown in Figure 8-2. The profile shows that giant Tsunamis occurred about every one thousand years. According to such records, simulations of Tsunamis have been implemented under an assumption of the three worst cases of giant earthquakes of Nanaki, Tonakai and Tokai, which occurred at the Nankai Trough in 1707 (called Hoei Great Earthquake with Tsunami and the eruption of Mt. Fuji 49 days afterwards). The result of the simulations in this worst case showed that a Tsunami higher than 10 to 30 m would occur along wide areas of the Pacific coast as shown in Figure 9. The detail topographic survey of the land portion, as well as the sea bottom are very necessary for the simulations.

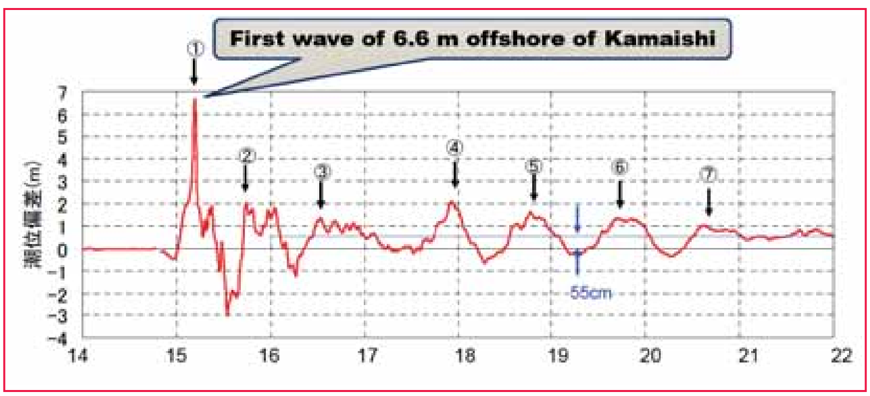

Figure 7: Tsunami Height Record

Relocation of residential zones to higher land

Relocation of residential zones to higher ground will be a key point to avoid future devastation and loss of life. However

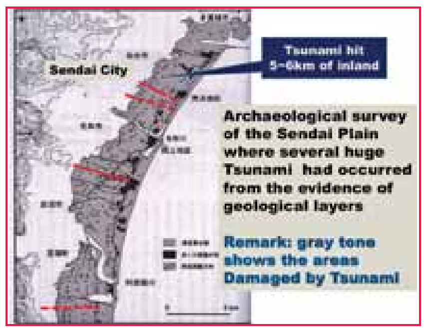

Figure 8: 1 Archaeological excavation

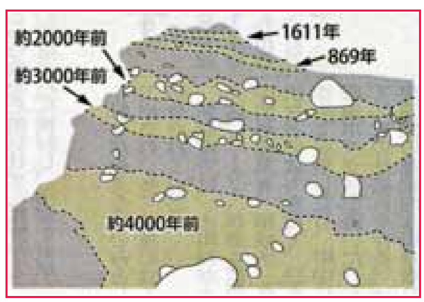

Figure 8: 2 Geological layers showing the past Tsunami

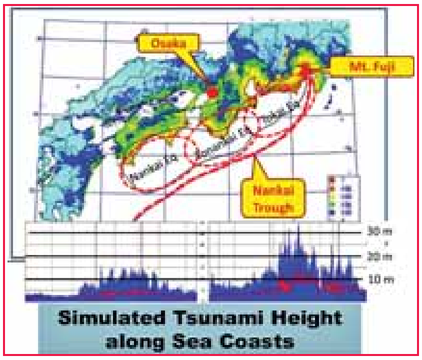

Figure 9: Assumed giant Tsunami

Figure 10: Relocated Yoshihama Village

Figure 11: Relocated Aneyoshi Village

there are many reasons to resist such a plan because some people, particularly fishermen, like to stay near the sea coast and some others don't like to leave the mother land. The central government as well as the local governments attempt to relocate towns and villages to higher ground 20 to 30 meters above sea level, though fishery industries will be allowed to locate near the coast if they prepare good evacuation measures.

We have to learn from past experience of our ancestors who made smart decisions to relocate their residential zones to higher ground. For example Yoshihama fishermen in Iwate Prefecture relocated their village to higher ground after serious devastation by Meiji Tsunami in 1896 and Showa Tsunami in 1933. Figure 10 shows Google Earth image of Yoshihama Village with houses located on higher ground, where rice paddy fields located on the site of the former village were damaged by Tsunami this time. Another example shown in Figure 11 is the case of a small fishing village called Aneyoshi Village in Iwate Prefecture which suffered badly from the Meiji and Showa Tsunamis when most villagers died except for only a few persons. Those survivors decided to relocate their village to higher ground 60 meters above the sea level. In order to remember such a catastrophe, they constructed a stone monument at the limits of the Tsunami inundation writing "Don't built any house lower than this stone monument. Don't forget the past Tsunami and then the villagers will have a happy and safe life".

One of the difficulties is to achieve consensus amongst the residents to all move to higher ground by selling their properties in their 'old mother land'. Nowadays we have only a few cases which have succeeded to gain the approval of the residents and local government. Without such relocation plans, the total city plan could not be progressed. In my opinion it would take more than five years achieve such a decision.

Reconstruction of smart cities

In spite of difficulties mentioned above regarding relocation of residential zones, a new concept of the "smart city" is being proposed for the reconstruction plan. Smart cities will provide solar energy power systems, high speed communication networks, high rates of recycling, mass transportation systems, self-supporting water supply and so on. It would be better to construct such smart cities rather than just to renovate original cities. The government is now encouraging such concepts for the reconstruction. Several cities have already proposed smart city construction.

For example Taro District in Iwate Prefecture which was heavily damaged by the Meiji Tsunami in 1896 with a high rate of 80 % of victims amongst the residents is making a new city plan. The District was hit and devastated seriously this time by the Tsunami even though the District should have been protected by 10 m high and 2.4 km long breakwater as shown in Figure 12. But this breakwater called "Taro Great Wall" was unbelievably devastated by Tsunami. Figure 13 shows one of the proposals which include a concept of smart city with solar energy power

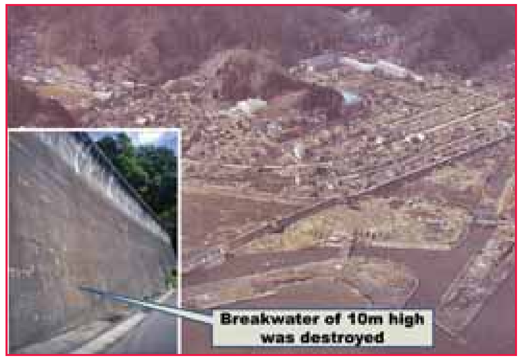

Figure 12: Devastated Taro District

Figure 13 Reconstruction Plan of Taro District

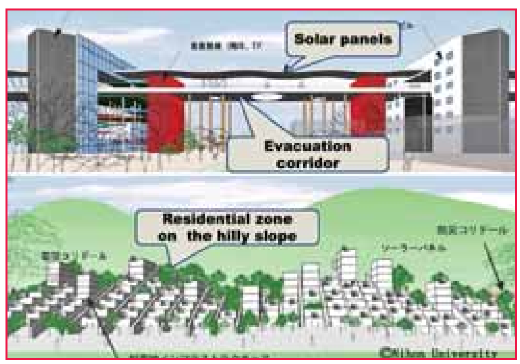

Figure 14: Reconstruction plan

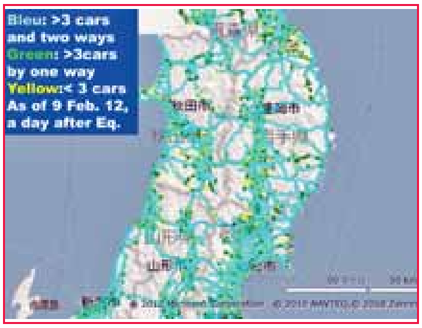

Figure 15: Sample of passable roads

Figure 16: Ancient road and towns

generation, safe guaranteed residential zones to be relocated on hilly land, highly elevated roads and bridges to assure transportation and rescue, evacuation towers, connecting corridors between buildings and others (see Figure 14).

Smart mapping of passable roads

Car travel records in operation with car navigation system with GPS are transmitted to a data center of the car makers. Therefore the data center can make a map showing which individual cars passed which roads and how many times at certain times. This map displays 'passable roads'. Toyota and Honda car industry provided the passable road map every day to Police Bureau and Defense Agency for rescue purposes after the earthquake and Tsunami. Figure 15 shows a sample of passable roads which indicates that the blue colored roads were updated every day. They were very useful for rescue patrol to reach the devastated areas as well as for the road recovery team to plan reopening of roads.

It is interesting to know that an ancient road and several ancient towns constructed about 5 to 6 km far from the sea coast line in the Sendai Plain were not damaged by the Tsunami as shown in Figure 16. The left figure shows the location of the ancient road and towns while the pink color indicates the inundated area of Tsunami. The right figure shows a satellite image of the same area. Ancient people might have learned lessons from past experiences of devastation. This is a good example of being well prepared.

Processing rubble and solid waste

The total volume of rubble and solid wastes is estimated at 24 million tons. According to Japanese regulations, the rubble and solid waste should be treated as industrial deposits which need to be classified into various classes. Therefore it will take time to gather and classify the rubble and solid waste. Ishinomaki City in Miyagi Prefecture was most seriously devastated with about 4,000 victims and six million tons of rubble and solid waste equivalent to the volume of accumulated waste of 106 years. At first thousands of unusable cars should be collected and dumped in a certain area. Other rubble and solid waste are being processed but it takes time and money. Professor Akira Miyawaki, who is a prominent ecologist, is proposing to use the rubble and solid waste as filling to construct a high bank instead of concrete breakwater together with environmentally friendly forests to lessen the power of a future Tsunami. The rubble mounds would be strong enough to withstand a Tsunami and protect residential zones behind them as shown in Figure 17. The author is proposing to construct keyhole burial mounds using the rubble and solid waste similar to the keyhole burial mounds of ancient times in the 5th century which were a unique tradition of Japanese religion, and used for an Emperor's Tomb. The author thinks that we need to construct a memorial for praying for safety and happiness of nations on the occasion of such a catastrophe. The keyhole tomb of Nintoku Emperor constructed in the 5th century is the largest burial mound in the world as shown in Figure 18. The author proposes circular keyhole burial mounds 36 m high and 311 meters in diameter as a memorial of the earthquake and Tsunami which occurred on March 11 – 311- as shown in Figure 19. This burial mounds would become the largest in the world. At least once a year, all relatives of the victims and other related people will be able to join at this park and pray for safety for the future. The keyhole tomb will be surrounded with a green belt and waterways and the surface of the rubble mounds would be covered by soil to allow for plantation of trees on the slopes.

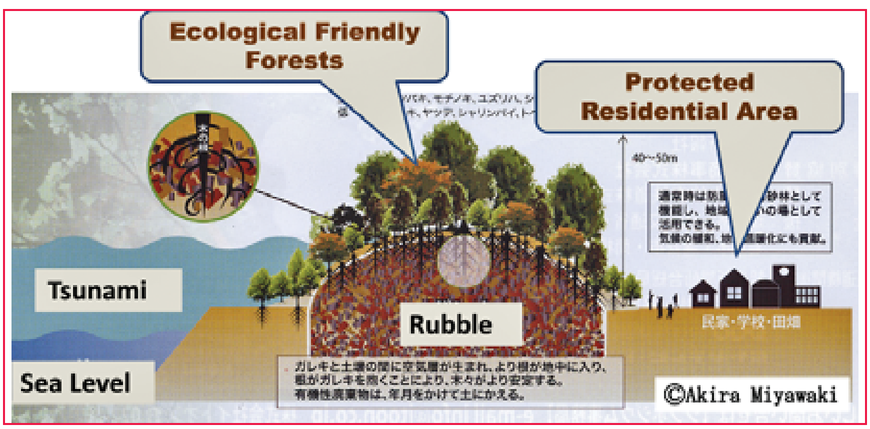

Figure 17: Breakwater with dumped rubble

Figure 18: World biggest Keyhole Burial Mounds of Emperor Nintoku made in the 5th century

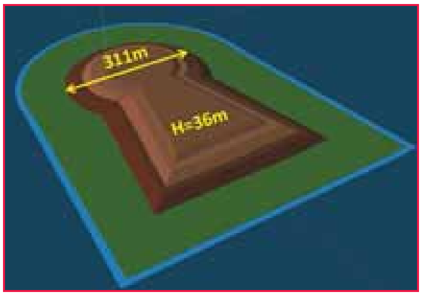

Figure 19: Keyhole Burial Mound with use of rubble proposed by Shunji Murai

Figure 20: Video scene of hydrogen gas explosion

Recovery from the accident of Fukushima NPS

The meltdown of nuclear fuel bars at three reactors out of four at Fukushima No. 1 NPS caused a hydrogen gas explosion as shown in a video scene of Figure 20. A satellite image shows the accident after the explosion of No.3 and No.4 reactor (see Figure 21). This human made accident caused the spread of tremendous amount of radioactive radiation equivalent to 30 atomic bombs dropped on Hiroshima in 1945. Without cooling from fresh water supply and sea water circulation, those fuel bars including spent fuel bars heated up to 2,800 degree Celsius which may have caused the hydrogen gas explosion. The reason why we recognize this as a human made accident is that none of experts expected such an explosion and blindly believed in its safety. Tokyo Electric Power Supply Company (TEPSCO) was not at all prepared for such an accident.

The radioactive contamination has spread over wide areas even including Tokyo, 250 km away from Fukushima NPS as shown in Figure 22. If you look at the vicinity of Fukushima NPS, access is prohibited for some areas even beyond 30 km (subject to over 50 milli sievert (mSv.) per year) from Fukushima NPS, while some parts more than 50 km away are not livable (over 20 mSv. per year) depending on wind direction as shown in Figure 23.

A question arises whether there is smart solution to solve the problems caused by such accidents. My answer is that there is no solution. This is because the radioactive radiation will continue almost forever and also we cannot clean up all the contaminated land by stripping off the contaminated surface soils and washing away the contaminated roofs, roads and others. Now local governments are trying to clean up contaminated areas, but they have no idea where such contaminated deposits should be dumped because local people are strongly against locating dumps near their houses. The volume of such contaminated soils is far larger than the capacity of dumping sites.

In addition all food and drinking water should be below the upper limit of radiation for health care to guard against the possibilities of residents contracting various forms of cancer. The governmental standard is; food less than 100 Becquerel (Bq.), milk less than 50 Bq. and water less than 10 Bq. Normal living conditions should prescribe exposure of less than 100 mSv. per year which should be lessened to 10 mSv after 2 years of exposure. The final target will be 1 mSv. per year. People don't believe governmental actions and they start to measure the radiation themselves to confirm safety. Moreover the government, as well as TEPSCO, have no idea how to shut down the damaged reactors. They cannot investigate even now the level of the melt down of the nuclear fuels which are located under contaminated water. Only robot arms 40m long would be able to pick up those fuels but nothing is planned yet. It means radioactive radiation will continue to contaminate the vicinity for many years until complete shutdown.

Figure 21: Fukushima No. 1 NPS showing the accident

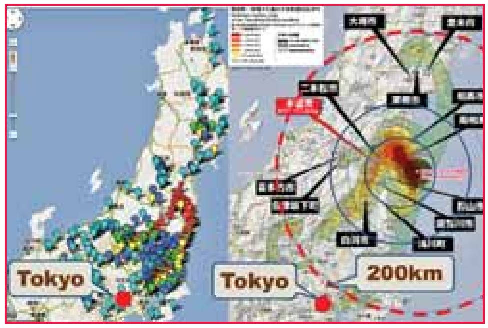

Figure 22: Hot Spots of Radio-active Contamination

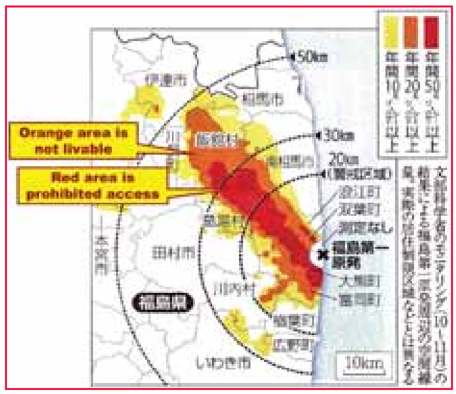

Figure 23: Annual Contamination

Conclusions

Construction of smart communities would be the best solution for preparedness against future catastrophic disasters. There is nothing absolutely safe in the case of Nuclear Power Stations. Therefore a small country such as Japan which also is disaster prone should not allow construction of any more nuclear power stations in order to ensure sustainable happiness.

Reference

Murai, Shunji; Higher Ground: Learning from the Great East Japan Tsunami and Meltdown at Fukushima NPS, Geomares Publishing, Lemmer, The Netherlands, 2012


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Developing Rural India

"We experiment and develop models for sustainable development"

Says Dr M V Rao, IAS, Director General, National Institute of Rural Development, Ministry of Rural Development, Government of India

Rural poor are focus of National Institute of Rural Development (NIRD). How does NIRD help them?

NIRD's primary mission is economic and social development of rural people, particularly rural poor and the underprivileged. We undertake capacity development of functionaries involved in rural development across the country. We experiment and develop models for sustainable development. Our research studies help to analyze development policies and programmes. We suggest corrective action in design and implementation method based on our field studies.

What are the key areas of your Training Programmes?

The Key Areas of NIRD Training Progranmmes are Livelihoods, Gender Issues, Equity & Social Development, Rural Technology, Natural Resources Management, Watershed Development, Rural Employment, Rural Industries, Basic Amenities like Drinking Water & Sanitation, Rural Energy, Rural Roads, Rural Health, Geoinformatics & ICT Applications, Financial Inclusiveness, and other rural development themes.

What is the main focus of research activities at NIRD?

NIRD's main focus of research is to study implementation of rural development programmes at field level and bring out policy and design issues for consideration of Central and State Governments. We also undertake policy research and evaluation of several initiatives at work across the country. We suggest ideas for new programmes and initiatives based on people's need and aspirations.

How do other NIRD Faculty Centres take benefit from Centre on Geoinformatics Application in Rural Development (CGARD)?

Other NIRD Faculty Centres take the benefit from CGARD in terms of training in National and International training programmes, mapping, Research Data Analysis, satellite data procurement and analysis and GPS data for locational aspects of assets, etc.

Do you like to highlight three main achievements of NIRD?

Though there are many landmarks in NIRD's over fifty years of service to the nation, the three significant achievements and contributions of NIRD are:

Deliberations and brainstorming leading to the formulation of 73rd Constitutional amendment for Panchayat Raj for decentralized governance and Right to Information Act (RTI) empowering people and ensuring transparency; and policy support and inputs to 10th, 11th& 12th Finance Commissions.

What role you see of Geoinformatics Technology in rural development?

Geoinformatics is proving to be a powerful tool for planning, monitoring, project implementation and evaluation of rural development programmes, for saving time and costs and hence in almost all rural development programmes, Geoinformatics applications are gaining acceptability and popularity because of usefulness. Further digital database, locational features, convergence and real time updating has made this technology an integral part of rural development policies and programmes.

Do you think there is a need for developing a RD GIS by CGARD?

As Geoinformatics help in convergence and real time data capturing, it is meaningful to have RD GIS to cater to the requirements of rural development. The RD GIS could optimize the benefits to the rural people and areas to develop the efficacy of the planning and monitoring systems.

What are NIRD Policies and Programmes to reach out to Villages to use Geoinformatics Technology?

NIRD encourages Faculty Centres to adopt villages and develop the villages through various development interventions by participatory means and the use of futuristic technologies like the Geoinformatics. CGARD has Action Research Projects in 4 Gram Panchayats in Tamilnadu and Maharastra and is going to take up three more in Karnataka, Andhra Pradesh and Kerala. Further, all projects undertaken by CGARD have applications up to village level. A standalone and web based Village GIS has been developed by CGARD. For two districts in Uttarakhand, cadastry level application has been developed.

“We have developed many customized Geoinformatics applications”

says V Madhava Rao, Professor & Head, CGARD, NIRD, Ministry of Rural Development, Government of India

What are the applications of geo-information technology in rural development?

The major application of Geoinformatics in rural development sector primarily are natural resources development, watershed development, Mahatma Gandhi National Employment Guarantee Scheme asset monitoring, rural roads, drinking water & sanitation, rural health, agriculture, animal husbandry, minor irrigation, soil conservation, afforestation, disaster management, land records & revenue and a host of other related applications.

How have been the response of your training Programmes?

The response of our Training Programmes are very encouraging, We get overwhelming requests from State Governments, District Administration, Sectoral Departments, NGO Sector for training programmes every year.

What are the main challenges in conducting training programmes?

The major challenges in conducting training programmes in this area are lack of computer infrastructure, converting the Training materials, Process Methodology and Manuals into Hindi and other regional languages and field personnel not getting sufficient days for hand holding practical sessions.

Have you developed any customized Geoinformatics application for rural development sector?

CGARD has developed many customized Geoinformatics applications, notable of which is appropriate identification of watershed treatment structures using Geo Hydrology Model, developed Customised Estimation Software with local language interface on Watershed for 11 States viz. Arunachal Pradesh, Assam, West Bengal, Orissa, Bihar, Chhattisgarh, Uttar Pradesh, Himachal Pradesh, Andhra Pradesh, Tamilnadu and Kerala and is in the process of developing Estimation Software for all States by the end of March 2013. GIS interface is also attempted for Estimation Software. Further a web based SDSS for convergence of Watershed and other

RD Programmes is also being prepared. In agriculture sector, a knowledge data base, viz. Agro Climatic Planning & Information Bank (APIB) with 18 layers of data, plot wise have been developed for farmers advisory and field functionaries for planning and monitoring, at 1:10,000 scale. An ICAR project on Farmers Advisory using Mobile is ready for implementation in Andhra Pradesh in KVKs of two districts, which is taken up in a Consortium mode with other Resource Organisations.

Does your Centre also undertake research activities?

Research is an integral part of CGARD Centre and currently engaged in research projects on Geoinformatics applications in Watershed, MGNREGS, Village Development, Agriculture, Soil survey, profiling & mapping, Developing SDSS etc. We have also undertaken Watershed Impact assessment using Geoinformatics for selected watersheds in many States.

How do you take Geoinformatics Technology to local level applications?

CGARD is relentlessly evolving systems and processes for taking Geoinformatics Technology to local level with use of Open Source Software, local language interface, mobile based application, extensive hand holding at field level, establishment of five(5) CGARD Centres at Guwahati, Bhubaneswar, Hyderabad, Ralegaon Siddhi and Ahmedabad and developing Server based access to field functionaries for Geoinformatics applications.

What will be your thrust areas in establishing the CGARD Centres in Africa and ICT Centre in Bangladesh?

The thrust areas in establishing the CGARD Centres in Africa and ICT Centre in Bangladesh are to reach out to the developing world, in sharing the innovative and best practices in Geo-ICT technology applications, creating manpower pool by developing their technical skill and knowledge level, familarisation of processes and methodologies, so that country specific Geo-ICT applications can be developed by these Centres.

"There is less awareness about Geoinformatics"

Says Dr S K Singh, Director, Training Division, Centre for Integrated Rural Development for Asia and the Pacific (CIRDAP), Dhaka, Bangladesh

What are your initiatives regarding the introduction of Geoinformatics technology?

We are organizing exclusive training programme for our member countries on Geoinformatics at least one every year. Usually, we have collaborative partner from India, the National Institute of Rural development. This programme is highly rated and there is demand for it. Moreover, we keep one slot on Geoinforation in other training programme, if relevant to theme. It is also well received.

CIRDAP is expecting computer lab funded by Government of India, Ministry of Rural Development. It will be ready by Feb 2013. Once it is in position, we will have more programmes on this topic.

What are the main factors you keep in mind while conceptualizing a training programme?

We conduct Training need assessment among member countries to ascertain their training requirements. Moreover, we also look into topical issues and theme while formulating training requirement. Cirdap has a Technical Committee comprising heads of all Link Institutes every year. Training needs are also discussed in the meeting. Of course, there is divergent opinion on themes, but Geoinformatics always find place in the requirements. Cutting across divergent training needs, these topics get paramount importance. For nomination to our programme, we ask our contact ministries from member countries to nominate relevant officers from senior/middle level. It is true, we get heterogeneous group with various level of understanding, however, technically they are normally abreast with, except language proficiency.

Centre for Integrated Rural Development for Asia and the Pacific (CIRDAP) is an Intergovernmental organisation mandated to facilitate the provision of services that will influence policy formulation and programme action towards rural development and poverty alleviation through a network of CIRDAP contact ministries and link institutions.

The objectives of the Centre are:

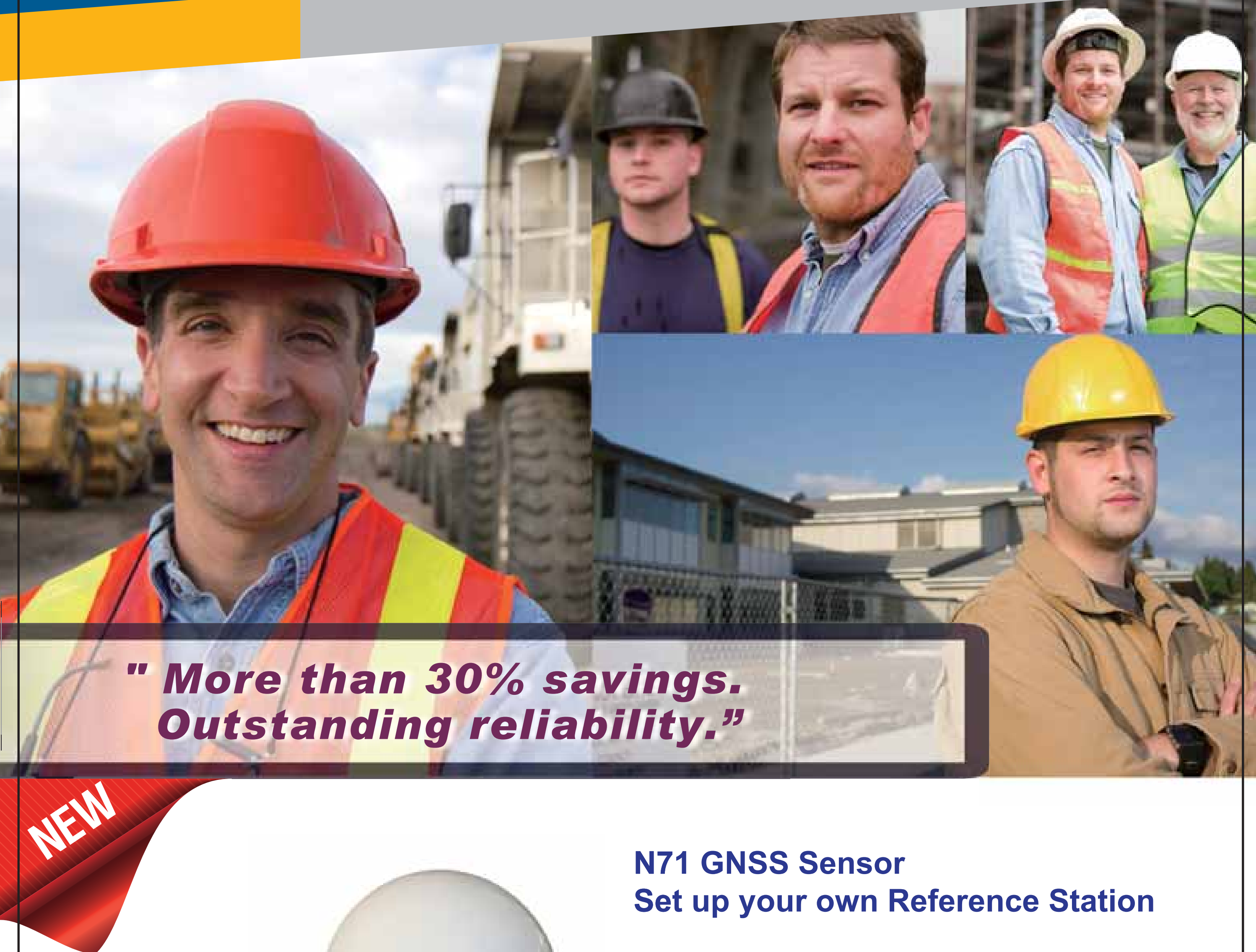
- To assist national action and promote regional co-operation relating to Integrated Rural Development (IRD), in the region
- To act as a servicing institution for its member states
- To encourage joint collective activities to benefit the member countries both individually and collectively
- To poverty alleviation through people's participation in the development process.

How do you cope up with the fast pace of evolving technology?

We are in touch with all important actors who are developing various new packages and try to take it and use it.

Do you feel that there is a poor awareness and sensitisation among field functionaries and decision makers on Geoinformatics?

Undoubtedly, there is less awareness about Geoinformatics and its utility among practitioners and decision makers. This is a good tool and plays enabling role in planning process. Therefore, it essentially calls for sensitising them. Such effort will give good result.



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On the high precision prediction of short-term polar motion

Combinational model of least squares and ARMA (p,q) has been applied to predict polar motion

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Polar motion refers to the earth rotation axis and surface intersection point's slow moving on the earth surface [1], real-time acquisition of polar motion is of great significance to high precision satellite navigation, satellite laser ranging and deep space exploration. At present, the international high accuracy polar motion value is obtained through VLBI and SLR technology observation data calculation. Due to its complicated calculating process, we cannot get real-time results, often need a delay of 2~5 days. Because of this condition, high precision short-term polar motion prediction has very important practical significance; therefore many scholars have put forward various methods to forecast the polar motion value [2-7]. These methods mainly use least squares algorithm to fit the polar motion's sure part and establish extrapolation model firstly, and then predict the stochastic part by employing artificial neural network model [2], Auto-Regressive model [7] and so on, finally add the least squares extrapolated value and the prediction value of stochastic part and take it as the forecasting polar motion value. We find that Auto-Regressive and Moving Average Model can best fit the stochastic part of polar motion when we analyze the polar motion's stochastic part time series, thus this paper try to employ LS+ARMA(p,q) model to forecast polar motion value.

LS+ARMA(p,q) model

LS model

The sure part of polar motion is consist of long-time trends, Chandler Wobble, Annual Wobble and Semi-Annual Wobble, thus the polar motion X and Y component can be expressed like formulas (1), (2).

$$X(t) = a_x + b_x t + c_x^1\cos(\frac{2\pi t}{P_C}) + c_x^2\sin(\frac{2\pi t}{P_C}) + d_x^1\cos(\frac{2\pi t}{P_A}) + d_x^2\sin(\frac{2\pi t}{P_A}) + e_x^1\cos(\frac{2\pi t}{P_{SA}}) + e_x^2\sin(\frac{2\pi t}{P_{SA}}) \quad (1)$$

$$Y(t) = a_y + b_y t + c_y^1\cos(\frac{2\pi t}{P_C}) + c_y^2\sin(\frac{2\pi t}{P_C}) + d_y^1\cos(\frac{2\pi t}{P_A}) + d_y^2\sin(\frac{2\pi t}{P_A}) + e_y^1\cos(\frac{2\pi t}{P_{SA}}) + e_y^2\sin(\frac{2\pi t}{P_{SA}}) \quad (2)$$

Where a_x、 b_x represent parameters of linear trends in X component, c_x^1、 c_x^2 represents parameter of Chandler Wobble in X component, d_x^1、 d_x^2 represent parameters of Annual Wobble in X component, e_x^1、 e_x^2 represent parameters of Semi-Annual Wobble in X component, P_C、P_A、P_{SA} represent cycles of Chandler Wobble, Annual Wobble and Semi-Annual Wobble, t represents UTC time. Parameters in formula (2) have the analogy meaning. If there are N polar motion values, observation equation can be written in matrix form like formula (3).

$$L = BX \quad (3)$$

Where :

$$L = \begin{bmatrix} X(t_1) & Y(t_1) \\ X(t_2) & Y(t_2) \\ \vdots & \vdots \\ X(t_N) & Y(t_N) \end{bmatrix}_{N\times 2} \qquad X = \begin{bmatrix} a_x & a_y \\ b_x & b_y \\ \vdots & \vdots \\ e_x^2 & e_y^2 \end{bmatrix}_{8\times 2}$$

$$B = \begin{bmatrix} 1 & t_1 & \cos(\frac{2\pi t_1}{P_C}) & \cdots & \sin(\frac{2\pi t_1}{P_{SA}}) \\ 1 & t_2 & \cos(\frac{2\pi t_2}{P_C}) & \cdots & \sin(\frac{2\pi t_2}{P_{SA}}) \\ \vdots & \vdots & \vdots & & \vdots \\ 1 & t_N & \cos(\frac{2\pi t_N}{P_C}) & \cdots & \sin(\frac{2\pi t_N}{P_{SA}}) \end{bmatrix}_{N\times 8}$$

Where X is parameter matrix of least squares model, B is coefficient matrix, L is observed value matrix, here, observed values have the same precision and they are independent of each other. Result can be obtained by using indirect adjustment; formula (4) expresses its specific form.

$$\hat{X} = (B^T B)^{-1} B^T L \quad (4)$$

We can get least squares model of polar motion sure part based on parameters which can be calculated form formula (4).

ARMA(p,q) model

Analytically, consecutive values of polar motion stochastic part have dependency relationship, and ARMA(p,q) model can ‘remember’ the dependency relationship of time-series well [8], we can use its memory performance to forecast values in the future. ARMA (p,q) model can be expressed in formula (5).

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \ldots + \phi_p Y_{t-p} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \ldots - \theta_q e_{t-q} \quad (5)$$

Where $Y_t (t=1,2,\ldots)$ represent polar motion stochastic part values, $e_t (t=1,2,\ldots)$ represent white noises, p and q indicate model orders, $\phi_i (i=1,2,\ldots, p)$ and $\theta_i (i=1,2,\ldots, q)$ indicate model parameters.

Model orders and parameters need to be estimated if we want to establish a ARMA (p,q) model. There are some ways to determine model orders, such as minimum error variance criteria, AIC criteria, BIC criteria, ESACF criteria [9] and so on, this paper employ ESACF criteria to estimate model orders *p* and *q*. ESACF is a kind of consistent estimate based on AR part parameters, and it does not require high stationarity of the process. In the estimate part, ESACF adopt iterative stepwise regression method. And we can acquire model orders by using ‘Triangular truncation’ of ESACF. As a example, the ESACF of ARMA (p,q) is given in Tab.1. Parameters of the ARMA (p,q) model must be calculated after the model orders is determined. There are also some methods we can use to estimate them, such as moment estimation method, maximum likelihood estimation method and least squares method and so on, this paper employ least squares method to estimate the parameters of the model. Stochastic part of polar motion can be forecasted when the model orders and parameters are estimated.

Numerical example

Standard for precision evaluation

This paper employs Root Mean Square Error (RMSE) and Mean Absolute Error

Table 1: ESACF for ARMA (p,q) model

AR\MA	0	1	.	q-1	q	q+1	.	L
0	×	×	×	×	×	×	.	×
1	×	×	×	×	×	×	.	×
.	×	×	×	×	×	×	.	×
p-1	×	×	×	×	×	×	.	×
p	×	×	×	×	0	0	.	0
p+1	×	×	×	×	×	0	.	0
.	×	×	×	×	×	×	.	0
L	×	×	×	×	×	×	.	0

(MAE) to evaluate the predicted polar motion values. Their calculation formulas are formula (6) and formula (7).

$$RMSE_i = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(P_j^i - O_j^i)^2} \quad (6)$$

$$MAE_i = \frac{1}{n}\sum_{j=1}^{n}|P_j^i - O_j^i| \quad (7)$$

Where P_j indicates predicted polar motion value at time interval *j*, O_j indicates real polar motion value at time *j*, *i* indicates forecasting span, $RMSE_i$ indicates RMSE for *i* forecasting span, MAE_i indicates MAE for *i* forecasting span.

Optimum length of fitting data for prediction

This paper forecasts polar motion values at a span of 1~20 days on the periods from January 1, 2005 to December 20, 2011 by using 6,9,12 and 15 years data before prediction period. Figure 1 shows the accuracy statistics.

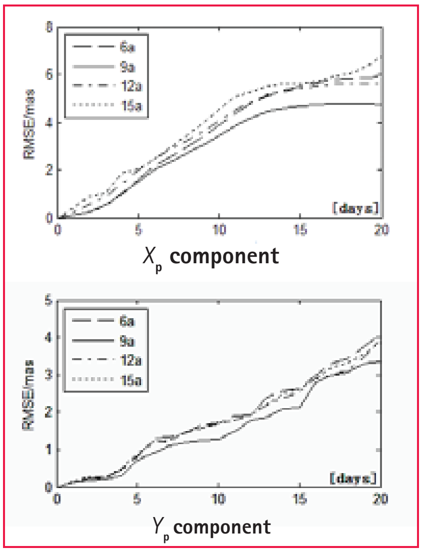

Figure 1: Prediction RMSE of Models Based on Different Length of Fitting Data

From Figure 1, we see that 9 years fitting data is the best length of fitting data to forecast polar motion values, therefore we use 9 years data to establish models. We also see that forecasting accuracy by using 6, 12, 15 years data is lower than by using 9 years data. It mainly owing to on one hand short-term data cannot effectively weaken observation errors’ influence, on the other hand long-term data cannot reflect time varying feature [10] of Chandler Wobble and Annual Wobble. Thus appropriate length-selection of the fitting data is very important.

Accuracy-Comparison with other prediction models

In order to test the superiority of LS+ARMA (p,q) model, we forecast polar motion values at a span of 1~20 days by using the method in this paper and other methods on the same condition. Figure 2 shows the results statistics on the period from January 1, 2005 to December 20, 2011.

From Figure 2, we can see that higher accuracy can be got from the LS+ARMA (p,q) model than LS+AR model.

To further prove feasibility of LS+ARMA(p,q) model, this paper try to forecast polar motion values on period from October 2005 to February 2008 (the same period with EOP PCC [11] which

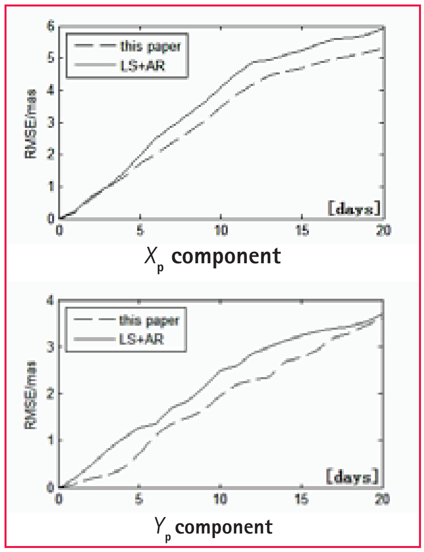

Figure 2: Prediction RMSE comparison with LS+AR model

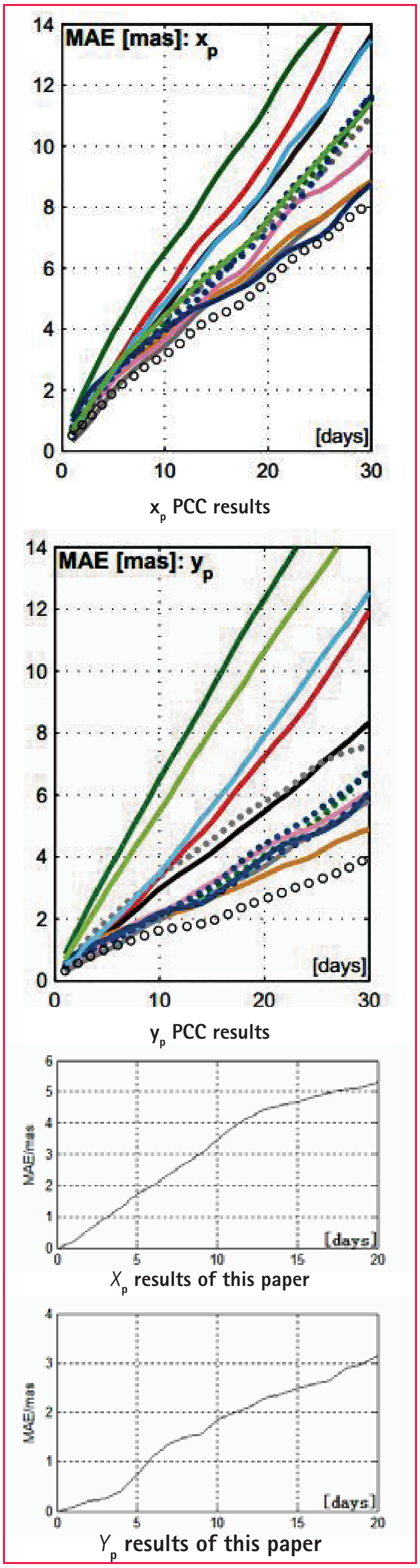

Figure 3: Prediction MAE comparison with EOP PCC

was launched by Schuh.etc in 2005). And we compare the results with EOP PCC in Figure 3 (different color lines represent different forecasting results in EOP PCC results). From Figure 3 we see that this paper's result is equivalent to the best result of EOP PCC, thus we can use LS+ARMA (p,q) model to predict short-term polar motion values.

In addition, we compare forecasting accuracy of LS+ARMA (p,q) model and accuracy of CLS+AR model[6], LS+ANN model[2], we use the same prediction period and precision evaluation with article[6] and article[2]. The results are shown in Table 2, in Table 2, $RMSE_{PM}$ is calculated in formula (8).

$$RMSE_{PM} = \sqrt{\frac{RMSE_X^2 + RMSE_Y^2}{2}} \quad (8)$$

Where $RMSE_X$ indicates RMSE of X component, $RMSE_Y$ indicates RMSE of Y component. From Tab.2 we can see that accuracy of LS+ARMA(p,q) model is higher than other two models except that 1 day span prediction is lower than LS+ANN model.

Table 2 Prediction RMSE comparison with CLS+AR and LS+ANN model

span/d	models			compare with other two	
	this paper	CLS+AR	LS+ANN	CLS+AR	LS+ANN
	$RMSE_{PM}$	$RMSE_{PM}$	$RMSE_{PM}$		
1	0.31	0.36	0.29	13.9%	-6.9%
3	0.90	1.14	0.95	21.0%	5.2%
5	1.64	1.78	1.79	7.8%	8.3%
10	2.78	2.98	3.25	6.7%	14.5%
20	4.66	4.81	6.28	3.1%	25.7%

Conclusions

This paper uses LS+ARMA (p,q) to forecast polar motion values, numerical experiment shows its advantages and applicability. But we find that it's only suitable for short-term forecast. When the span is longer than 20 days, its accuracy is lower than other models. Physical motivating factors of polar motion have not been discussed in this paper, we only employ polar motion time series to forecast. These factors will be combined to forecast polar motion in the near future.

Acknowledgments

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Researchers told to ward off navigation system interference

Fan Changlong, vice chairman of the Central Military Commission, required researchers to beef up the security measures of the BeiDou Navigation Satellite System (BDS) and increase its capacity to ward off interference. The BDS began providing services to civilian users in China and surrounding areas in the Asia-Pacific region recently. He said the system has broken China's reliance on foreign navigation systems and carries great significance in safeguarding national security and promoting economic development. *www.spacedaily.com*

China's Beidou GPS-substitute opens to public in Asia

China has opened up its domestic sat-nav network to commercial use across the Asia-Pacific region. It had previously been restricted to the Chinese military and government. A spokesman said that Beidou is targeting a 70-80% share of the Chinese market in related location services by 2020. The China Satellite Navigation Office added that by that time it also intended the service to be available across the globe. *www.bbc.co.uk*

Putin urges CIS Countries to join Glonass

Russian President Vladimir Putin called on the members of the Commonwealth of Independent States (CIS) to join Glonass, Russia's equivalent to GPS. "This system has the capability to provide considerable benefits in the economic sphere, since it reduces cargo transportation costs on all transportation systems, and it definitely increases the safety of all types of transportation," he said. *http://en.ria.ru/world/*

New dates of Glonass-K satellite launches to be determined

New dates of launches of the Glonass-K satellite and a military spacecraft from the Plesetsk cosmodrome will be determined soon. Glonass-K is the latest satellite design intended as a part of the Russian GLONASS radio-based satellite navigation system. Developed by Reshetnev Information Satellite Systems and first launched on 26 February 2011, it is a substantial improvement of the previous Glonass-M second-generation satellites, having a longer lifespan and better accuracy. *http://www.itar-tass.com/en/*

Russian military's support of GLONASS on ice after corruption scandal

The Russian Defense Ministry has reportedly refused to adopt GLONASS, due to its technical shortcomings. One of the system's 24 satellites has malfunctioned, and besides, GLONASS is still in its testing phase. The malfunctioning satellite will not be operational any time soon as it has already exhausted its power after 96 months in service, Nezavisimaya Gazeta reports. And due to a difference in orbit inclination, no existing reserve satellite can substitute it. *http://rt.com/news/*

Roscosmos reaffirms Russia's commitment to Glonass

A draft statement from the space agency Roscosmos has reaffirmed Russia's commitment to maintaining Glonass for at least another 15 years. Prepared on the instructions of a working group set up by Deputy Prime Minister Vladislav Surkov, this is in accordance with International Civil Aviation Organisation (ICAO) Standards and Recommended Practices. *www.telegraph.co.uk/*

Navigation guarantee center set on N China Sea

A navigation guarantee center was opened in Tianjin to serve the navigation activities on the North China Sea. Together with two other centers on the South China Sea and East China Sea that are already in operation, the new center will guarantee the navigation service and promote the country's maritime economy.The center operates under the Maritime Safety Administration with the Ministry of Transport, and will incorporate navigation aid, surveying and mapping, and marine communication to support and serve navigation activities. *http://usa.chinadaily.com.cn/china/*

India on brink of launching satellite linked navigation services

India may soon roll out satellite -assisted navigation services in collaboration with Russia's NIS-GLONASS. The two countries, after talks between Prime Minister Manmohan Singh and Russian President Vladimir Putin, signed a memorandum of understanding recently for conducting the proof of concept through pilot project for providing the satellite-based navigation services. The MoU envisages a pilot project to assess the usage of GLONASS using the capabilities of BSNL/MTNL ground infrastructure. *http://articles.economictimes.indiatimes.com/*

Mapping from Wi-Fi "Fingerprints" Could Improve Indoor Navigation

The Korea Advanced Institute of Science and Technology (KAIST) has a new method to build a map from Wi-Fi radio signals without accompanying GPS tags or manual inputs of map coordinates. Most current systems need GPS signals to fully interpret the data coming from Wi-Fi routers. Dong-Soo Han, a professor in KAIST's Department of Computer Science, and his research team used software embedded in smartphone apps to upload a Wi-Fi fingerprint, that is, information about the current set of Wi-Fi signals and signal strengths available to the mobile device at that moment. Users were asked to input their home and office addresses. The mapping system developed linked the geographic coordinates of those locations to the Wi-Fi fingerprints most frequently collected by the smartphones, combining that information with those from other users to create an overall Wi-Fi radio map of a selected geographic area. Such maps could be used as the basis of indoor navigation or indoor location-based services (that, for example, send a coupon when you pass a particular restaurant in a shopping mall). Han's team tested the system in four areas of Korea with mixed residential and commercial locations. *http://spectrum.ieee.org/*

China launches Turkish remote sensing satellite

A Chinese Long March rocket successfully launched a Turkish remote sensing satellite last month. The 450-kilogram satellite, built by Turkey's Space Technologies Research Institute and Turkish Aerospace Industries, Inc., with a camera system provided by South Korea, is designed to provide imagery of the Earth at resolutions as high as 2.5 meters. *http://www.spacetoday.net/*

Source of Huaihe River Pinpointed with the help of RS

Chinese scientists have pinpointed the source of the Huaihe River and re-measured the length of the river, which, along with the Qinling Mountains, is regarded as the geographical line dividing China's north and south. The river is 1,252 kilometers long and its drainage area is 274,657 square kilometers, according to the new findings of the Institute of Remote Sensing Applications under the Chinese Academy of Sciences.

Liu Shaochuang, a leading scientist in the research project, said, "We found the longest headstream in the drainage basin of the river and pinpointed its source based on high-resolution remote-sensing images. Then we conducted field investigations to the source area to confirm the findings." *http://english.cri.cn/*

Remote Sensing Space Centre in Haiti

Within the framework of the bilateral cooperation France-Haiti, the Research Institute for Development (IRD) and the State University of Haiti (UEH) have signed an agreement for the establishment on the campus Roi Christophe (North), of an antenna of Environmental Monitoring Satellite Aided (SEAS). This antenna will allow to receive images of the Caribbean region, taken from various satellites. *www.haitilibre.com/en/*

New law in making - aerial photography banned in Hungary

In Hungary the state wants to forbid to taking photographs or images from the air. From early 2013 only 3 or 4 specially authorized universities and organizations can make close-air photos. The regulation also applies to foreign tourists. *http://www.hir24.hu/*

Iran to launch 2 new home-made satellites soon

Head of the Iranian Space Agency (ISA) has announced that the country is preparing to put two new home-made satellites, called AUT SAT and Sharif SAT, into orbit in the near future.

The Islamic Republic in February announced plans to display its new achievements in space fields by sending heavier home-made satellites to higher altitudes by the next few years. *http://english.farsnews.com/*

DigitalGlobe and MapBox bring Location Intelligence to every online user

With the new MapBox Satellite service, users can incorporate DigitalGlobe's high-resolution satellite imagery as their maps' base layer for added quality and ground detail. It also allows users to integrate crowd-sourced information directly from OpenStreetMap (OSM) for increased relevance and location intelligence. *www.digitalglobe.com*

DigitalGlobe- GeoEye merger approved by shareholders

Shareholders of imaging satellite operators GeoEye and DigitalGlobe have approved the merger of the companies in a transaction that would create a single major provider of commercial satellite imagery to the US Department of Defense, the companies announced. *www.digitalglobe.com*

US Congress reforms the export control framework for satellites

The Satellite Industry Association (SIA) congratulates the U.S. Congress for passing this year's National Defense Authorization Act (NDAA) that reforms the export control framework for satellites and related items. The satellite export control reform provision in the NDAA reverses a 1998 requirement to treat exports of satellites differently from those of other high-technology products, a reform that SIA has sought for over a decade.

The legislation will provide a more even playing field for U.S. satellite companies, spurring economic and job growth and bolstering the leadership of the U.S. Space community for many years. *www.sia.org*

Pléiades 1B satellite launched, joins Pléiades 1A

Astrium has announced successful launch of Pléiades 1B optical satellite. It joined its twin Pléiades 1A to form the first ever high-resolution earth-observation constellation of its kind. Astrium Services will be the exclusive distributor of imagery from Pléiades 1A and 1B.

This daily revisit capability of the satellite will bring added value to users of satellite data products around the world. *Astrium*

GeoEye announces first sale to the Government of India

GeoEye has received an order from the Government of India for stereo imagery from the high resolution GeoEye-1 satellite to support development of India's freight railway corridor. Stereo imagery provides three-dimensional viewing and feature recognition for a number of engineering applications, including three-dimensional feature extraction. RITES, a Government of India Enterprise, made the six-figure purchase through the National Remote Sensing Centre (NRSC), GeoEye's Master Reseller for India.

Galileo update

Third Galileo satellite begins transmitting navigation signal

Europe's third Galileo satellite has transmitted its first test navigation signals back to earth. The two Galileo satellites launched last October have reached their final orbital position and are in the midst of testing.

The third Galileo Flight Model, known as FM3, transmitted its first test navigation signal in the E1 band on 1 December, the band being used for Galileo's freely available Open Service interoperable with GPS. Then, on the morning of 4 December, the satellite broadcast signals across all three Galileo bands – E1, E5 and E6. *ESA*

2012 European Satellite Navigation Competition Results

This is the ninth year for the European Satellite Navigation Competition, which has grown from a Europe-only affair to an international competition with more than 400 submissions for GNSS applications ideas. The 2012 Galileo Master award was won by Portuguese team who use ULF-MC for wayfinding where GNSS can't go.

Finding your way indoors will be even easier with a new smartphone app from two Portuguese research institutes that augments GNSS with positioning using ultra-low magnetic field communication (ULF-MC).

Fraunhofer Portugal and the University of Porto's Faculty of Engineering received the €20,000 Galileo Master's prize for their innovation in this year's European Satellite Navigation Competition (ESNC 2012) awards. The ULF-MC application was the overall winner from among 406 completed entries (the most ever) submitted from more than 40 countries.

A panel of expert judges selected the Galileo Master from among the 24 winners in ESNC competitions held by regional partners. The ESNC is sponsored by the European GNSS Agency (GSA), the European Space Agency (ESA), the European Commission, the Free State of Bavaria, and the German Space Center (DLR}. The competition is organized by Anwendungszentrum GmbH Oberpfaffenhofen (AZO), a Bavarian economic development and business incubation center.

EGNOS goes live at Milan Linate

Milan Linate airport has become the first in Italy to provide satellite-based EGNOS navigation services to all operators at no cost. Other Italian airports are scheduled to soon follow in 2013 in line with Italy's national Performance Based Navigation implementation plan.

EGNOS approach procedures offer enhanced vertical guidance improving safety, accessibility and efficiency to operators, pilots and airports and also provide a cost effective alternative to ILS CAT I as they offer similar performance without the need for infrastructure installation and maintenance. *www.airtrafficmanagement.net/2012/12/egnos-goes-live-at-milan-linate/*

First copy of UAE electronic statistical atlas launched

The National Bureau of Statistics (NBS) has launched its first copy of the UAE's electronic statistical atlas. It comes within the framework of the strategic initiatives of the NBS to meet requirements of data users. The atlas is the latest sophisticated data device linked to the GIS technologies and their applications. *http://gulfnews.com*

New survey technique offers detailed picture of our changing landscape

A new surveying technique developed at The University of Nottingham is giving geologists their first detailed picture of how ground movement associated with historical mining is changing the face of our landscape.

The new development by engineers at the University has revealed a more complete map of subsidence and uplift caused by the settlement of old mines in the East Midlands and other areas of the country and has shown that small movements in the landscape are bound by natural fault lines and mining blocks. *http://www.nottingham.ac.uk*

Restoring the Great Lakes through mapping

A team of researchers in US from the University of Michigan and the University of Wisconsin – Madison produced the most comprehensive map to date of the Great Lakes' stressors, and also the first map to explicitly account for all major types of stressors on the lakes in a quantitative way.

These maps open the discussion on global restoration. By making calculated decisions based on extensive data, the world's leading environmental issues can be approached with realistic solutions that can save time and money. Through a press statement, team leader and University of Michigan professor, David Allen, explained that the map represents the combined influence of

34 stressors on each of the five Great Lakes and ranks the importance of each stressor in relation to how it affects the lake itself. *www.theinternational.org*

Geoinformatics helping refugees in South Sudan

In South Sudan, UNHCR is using satellite imagery, interactive mapping, digital fingerprinting and text messaging to strengthen refugee protection, help the most vulnerable and reach out to refugees in urban areas. In Yida refugee settlement, the largest in South Sudan with more than 65,000 refugees, biometrics is a critical way for UNHCR to target services, to prevent multiple registrations and make planning and delivery more efficient. *www.unhcr.org/50dc5a309.html*

US$65m for digitising land parcels in Thailand

Department of Lands (DOL) under Ministry of Interior, Thailand will continue its ongoing "Cadastral Information Systems (CIS) project in digitising title of 32 provinces, with approved fiscal budget of THB 2 billion (US$ 65m) in 2013, said DOL Deputy Director General and CIO Thammasak Chana. The project will convert and transfer the title deeds of 14 million land parcels of 32 provinces from paper-based documents to digital data by leveraging and integrating ICT, MIS and GIS technology.

China to launch 1st national geoinformation survey

China will launch its first national survey that will examine the country's geographic conditions next year. The survey, with investment of about 1.1 billion yuan ($175m), will take three years to monitor China's nature and geographic conditions relating to humans. Information collected will consist of the country's territorial size, geological regions, topographic and geomorphic characteristics as well as road and transportation networks. *http://www.chinadaily.com.cn*

Google cash buys drones to watch endangered species

Drones could soon be helping protect rhinos, tigers and elephants in Africa and Asia, thanks to cash from Google. Controlled via a tablet computer, the small autonomous aircraft will photograph poachers and track animals via smart radio tags.

The World Wildlife Fund added the $5m grant would also fund software that could map where poachers strike. *http://www.bbc.co.uk/news/*

Draft Australia New Zealand Foundation Spatial Data Framework announced

Work in New Zealand and Australia to develop national spatial data infrastructures has been given a boost by the announcement from the Australia New Zealand Land Information Councils' vision for an Australian and New Zealand (ANZ) Foundation Spatial Data Framework. The vision for the ANZ Foundation Spatial Data Framework is that the same foundation spatial data will become common place in all sectors of the Australian and New Zealand economies.

'Foundation spatial data' describes the basic layers that are needed by users of location-based information. They are the original pieces of spatial information that are created by authoritative sources, like government agencies. Often, this information is collected for core business purposes by these agencies, and not made available in a consistent way, if at all. *www.linz.govt.nz*

IIT-Roorkee, India invents cost-effective virtual mapping tech

Replacing the costly laser technology for virtual mapping of any location or structure, the Indian Institute of Technology, Roorkee (IIT-R), has come up with a technological solution to 3D virtual mapping by using photogrammetry for the first time in the country.

The institute has now uploaded the sample of its work titled '3D model IIT civil org', a 3D model of the department of civil engineering and its surroundings, on YouTube, to get comments from industry and the general public.

According to the inventor, this technology will help any civil administration authority to mark the existing illegal encroachments on roads, in markets or other places in an effective way, with precision and accuracy to determine the exact area of that site and structure. *http://www.hindustantimes.com*

SLA and NYP Collaborate

The Singapore Land Authority (SLA) and Nanyang Polytechnic (NYP) signed a Memorandum of Understanding on 7 November 2012 to collaborate on geospatial education, training, research and development.

This strategic partnership would enable both organisations to tap into each other's expertise and resources in promoting the use of geospatial information system and technology in Singapore.

Myanmar braces for first census in 30 years

Dr. Khaing Khaing Soe, Deputy Director of the Department of Population at the Ministry of Immigration and Population in Myanmar, shares how the country is making preparations for its 2014 nationwide population census, the first in 30 years. Khaing shares that at present, the Ministry is currently leveraging GIS to streamline the workload in field operations.

"Even if our Department is only at the initial stage of GIS uptake, we are starting to see the tangible benefits of leveraging GIS. It helped us save time and energy by reducing redundant workflows. In addition, it also allowed us to make better decisions so we can effectively streamline our operations."

Northrop's navigation pact for India

Sperry Marine business, a unit of Northrop Grumman Corporation (NOC), will supply advanced shipboard navigation systems for 20 fast patrol vessels under a contract with Indian reseller Marine Electricals Ltd. The systems will be supplied to Indian Coast Guard.

The navigation package consists of VisionMaster Total Watch multifunction displays, electronic chart display and information system (ECDIS), autopilot, magnetic compass and the new NAVIGAT 3000 fibre optic gyrocompass. The pact includes spares, factory testing and engineering support services that will be supplied for fast patrol vessels to be built at Cochi Shipyard Ltd. India. *http://www.nasdaq.com/*

CEACT river navigation software updated

SevenCs and CEACT Information Systems Inc. have announced the latest development of their inland navigation system CEACTTM. The new version, available since November 2012 includes new functionalities. Multiple CPA enables the user to track several AIS targets simultaneously. The operator can toggle between the most relevant targets without re-acquiring. Dangerous targets don’t get lost and the situational awareness is significantly improved. *www.marinelink.com*

NVS Technologies selected by Alberding for sub-meter GNSS receiver

Alberding GmbH, a developer and distributor of professional GNSS system solutions, has recently announced the Alberding A07 personal navigator, featuring NVS Technologies AG’s NV08C-CSM high-performance multi-GNSS constellation receiver. The Alberding A07 is a low-cost single frequency GNSS receiver designed for personal navigation and other sub-meter accuracy positioning applications in an urban environment. *www.*nvs-gnss.com

BAE Systems selected to provide activity-based intelligence support for NGIA

BAE Systems has been awarded a multi-year $60 million contract to provide Activity-Based Intelligence (ABI) systems, tools and support for mission priorities for the National Geospatial-Intelligence Agency (NGA). This award is a task order under the NGA’s Total Application Services for Enterprise Requirements (TASER) program, a five-year Indefinite Delivery Indefinite Quantity contract.

BAE Systems’ ABI solution employs advanced software analysis tools integrated with commercial, off-the-shelf computing infrastructure to automate the ingestion, storage and processing of large volumes of intelligence data across multiple. *www.baesystems.com/intel*

Raytheon wins DARPA contract

Raytheon Company was awarded a $1.5 million Defense Advanced Research

Projects Agency (DARPA) contract for phase one of the agency's Space Enabled Effects for Military Engagements (SeeMe) program. During the next nine months, the company will complete the design for small satellites to enhance warfighter situational awareness in the battlespace. *www.raytheon.com*

New Pegasus HA500 ALTM

Optech Pegasus HA500 ALTM is a purpose-built wide-area mapping sensor that is expressly focused on maximizing collection efficiency. Capable of altitudes up to 5000 m AGL (16,500 ft), this powerful new sensor has the unique ability to collect multi-beam lidar data throughout its entire operating envelope, for industry-leading point cloud density and accuracy at any altitude. *www.optech.com*

Intergraph® Introduces GeoMedia 2013

Intergraph has announced the upcoming release of GeoMedia® 2013 as part of Intergraph Geospatial Portfolio 2013. A powerful GIS management package that enables users to realize the maximum value of their geospatial resources, it will provide further simultaneous access to geospatial data in almost any form, uniting them in a single map view for efficient processing, analysis, presentation and sharing.

Enlighten Business Intelligence version 3.0

Open Spatial has released Enlighten Business Intelligence version 3.0. It is a powerful web based GIS and decision support portal enabling seamless integration of engineering, corporate databases, imagery, mapping data and multimedia. The ability to drill down and drill through corporate data stores from a map is a main strength of the software.

Esri supports USAID-Funded Center

Esri will provide software, data, online services, training, and professional services support to the AidData Center for Development Policy. It was created with a five-year, $25 million award from the United States Agency for International Development (USAID). Esri's ArcGIS Online, along with other technologies, will provide a platform for taxpayers in donor countries, development organizations, and beneficiaries to draw on the largest collection of development finance activity data in the world through interactive maps and web and mobile applications.

CHC opens its European Representative Office

CHC Navigation has opened its European Representative Sales Office. Based in Nantes (France), this new office supports the expansion of its business units in Europe, Middle East and Africa, reinforcing CHC's presence worldwide.

JAVAD: TRIUMPH-VS software updates 1.10

New features include:

- Cycle-Slip Analyzer feature.
- GNSS Spectrum Analyzer feature.
- Spectrum Analyzer for UHF and FH915 radio modems.
- New Feature Codes system.
- Interactive surveying on the map.
- Offset Survey action.
- Delete objects by type feature.
- Corrections receiving and transmitting via Bluetooth.
- Advanced Video Settings for cameras.
- PAP and CHAP authentication for GPRS Network.
- External GNSS Antenna Calibration feature.

Also improved:

- External GNSS receivers support.
- Wi-Fi connectivity.
- TCP server functionality.
- Raw data files recording.
- Receiver options support.
- GSM module management.
- GSM status report.
- NTRIP and TCP clients setup and performance.
- Fixed Base Station action.
- Map Screen performance.
- External Antenna types support.
- Alphabetical Keyboard functionality.
- Visual Stakeout functionality.

Setting New Standards in Surveying via UAS

RIEGL Laser Measurement Systems and Schiebel Corporation are proud to announce the successful integration of the Schiebel CAMCOPTER® S-100 Unmanned Air System (UAS) together with the *RIEGL* VQ®-820-GU hydrographic airborne sensor. This successful integration marked the first time that this new airborne sensor was flown on board of a UAV.

NovAtel announces End of Life for WAAS G-II Reference Receiver

NovAtel Inc. is announcing the End of Life of the WAAS G-II Reference Receiver. These products will be available for order until June 30, 2013. Shipments may be scheduled for no later than December 31, 2013 and NovAtel will continue to support and repair these products until June 30, 2016.

NovAtel is currently completing qualifications for our next generation WAAS G-lll receiver, which will be commercially available in 2013. The standard G-lll platform will support dual frequency SBAS and form the basis of a commercial off the shelf (COTS) product for organizations seeking rapid evolution of their ground reference systems. *www.novatel.com/products/discontinued-products*

eB Insight V8i (SELECTseries 3)

Bentley Systems has announced the immediate availability of *eB Insight* V8*i* (SELECTseries 3). It provides records management enhancements that comply with the U.S. Department of Defense (DOD) 5015.02 Records Management standard. As a result, *eB Insight* is now listed in DOD's compliant Product Register and is ideally suited for all DOD organizations, contractors, and suppliers, as well as owner-operators of engineered infrastructure assets seeking health, safety, and environmental compliance. *www.bentley.com*

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Stipends are available for students to pursuit PhD in UNNC. Research projects can be in, but not limit to, the areas of GNSS for deformation monitoring, GNSS data processing algorithms, GNSS error modelling, GNSS for position, velocity and time determination, sensor integration (GNSS, INS, UWB, etc.), air-borne and terrestrial mobile mapping system, calibration of low cost digital cameras, optical & ranging sensor integration (Photogrammetry, Lidar, RADAR), feature extraction and object recognition, remote sensing techniques. Students are co-supervised by professors in The University of Nottingham in UK.

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"We can't leave our security to any other country"

-S Jaipal Reddy, Union Minister for Science and Technology and Earth Sciences, India at NAVCOM 2012, Hyderabad

The International Conference on Navigation and Communication (NAVCOM-2012) was held during 20 -21 December, 2012 at Hyderabad.

The chief guest Dr V K Saraswat, DRDO Director Generalans SA to RM, inaugurated the conference on 20th December, 2012. Later Talking to reporters on the sidelines of a conference, he said the India's own Operating System (OS) aimed at effectively preventing cyber attacks and threats would be ready in three years. Around 150 scientists and engineers have been working on the project at different places for the past one and half years.

Dr VK Saraswat said that the Indian OS was being developed as part of efforts to provide robust cyber security. The country needed to develop its own hardware and software systems in a big way.

Earlier addressing the conference, Sri Avinash Chander, Programme Director AGNI-V & CC R&D (MSS) called for developing cost – effective navigation systems. He said the DRDO was looking for a new class of systems with wide applications for both military and civilian use. The DRDO was upgraded its foundries for developing MEMS-based systems.

Mr A S Ganeshan, Project director, Navigation Systems, ISRO Satellite Center, Banglore said the GPS-Aided Geo Augmented navigation (GAGAN) will be ready for the users by the third quarter of next calendar year. He added that the Indian Regional Navigation Satellite System (IRNSS) with a constellation of seven satellites is expected to ready by the end of year 2015.

Mr G Satheesh Reddy, Associate Director, Research Center Imarat (RCI), said India was on par with advanced nations in developing navigation systems for both short range and long range missions with high accuracy. Osmania University Vice-Chancellor Prof. S. Satyanarayana and Prof A D Sarma, Director NERTU also addressed the delegates.

More than 450 delegates were present at the conference, including those from Israel, France, Russia and Australia. The conference was jointly organized by NERTU, Osmania University with DRDO, convened by Sri Manjit Kumar, Smt A Supraja Reddy and Sri V Satya Srinivas under the Chairmanship of Sri G. Satheesh Reddy and Prof A D Sarma.

Mr S Jaipal Reddy, Union Minister for Science and Technology and Earth Sciences speaking at the valedictory session of an international conference on navigation and communication emphasized that the research institutions and universities to forecast technological challenges and develop state of the art navigation and communication systems indigenously for the safety and security of the country.

The Minister said that the India is an ideal country for harnessing engineering workforce for the myriad needs of defence and civilian industries and for value added services. The country should create its own technologies apart from understanding the ones borrowed. "We can't leave our security to any other country, even if they are most friendly," as mentioned by Mr S Jaipal Reddy.

Europa Technologies deploys viaEuropa service for SeaZone

Europa Technologies has announced that its award-winning viaEuropa service is being utilised for marine mapping from SeaZone Solutions. HydroView Now offers global coverage of depth area features with shaded relief and intuitive depth soundings.

Working closely with SeaZone, Europa Technologies has deployed HydroView Now as a service with attractive cartography and the ability to consume the marine mapping in desktop GIS and web-based applications. *www.europa.uk.com*

StreetMapper helps improve Europe's highway safety

Dutch surveying company Geomaat has developed a unique method of measuring safety barrier heights on European roads. Using 3D Laser Mapping's mobile laser mapping system StreetMapper and automated feature extraction software, Geomaat can now process laser scanned point cloud to determine the height of the existing barrier.

The software then automatically codes the georeferenced 3d model, green for acceptable and red for requiring attention. *www.3dlasermapping.com*

TomTom launches LBS platform for rapid application development

TomTom has launched its new LBS Platform and Developer Portal. TomTom LBS provides developers with the content and tools to rapidly create location-enabled applications for a variety of commercial and consumer markets.

The cloud-based LBS Platform enables businesses to access TomTom's high quality location and navigation services including map display, routing, traffic and geocoding. *www.equities.com/*

AT&T in USA launches AT&T alerts

AT&T has announced AT&T Alerts, a service to help make shoppers aware of nearby deals via opt-in discounts delivered directly to their phones by SMS based on geo-location data. AT&T is clearly trying to capitalize on the same opportunity being targeted by Groupon, startups like Roximity, and other larger companies like Google, to name just a few. *http://techcrunch.com/*

Unibail-Rodamco selects Pole Star Indoor Location service

Unibail-Rodamco, European commercial real estate group with nearly 80 shopping malls, expands its partnership with Pole Star, leader on the indoor positioning market, to provide visitors with a real-time geolocation app, available for both Android and iPhone. NAO Campus® is the natural complement to Google Map Indoor, already deployed in some of the group's shopping centers. The new app adds a 3D interactive map and turn-by turn guidance so shoppers will never get lost again inside these large, complex venues. *www.oxygen-pr.com*

DEME group selects the TERRASTAR-D® service with Septentrio GNSS receivers

Septentrio has announced that DEME has selected the TERRASTAR-D® "Precise Point Positioning" service to work with its Septentrio GNSS receivers. The Belgian dredging and environmental group is exploiting the service using Septentrio AsteRx2eL GNSS positioning and AsteRx2eH GNSS heading receivers to support its nearshore dredging and construction operations worldwide. TERRASTAR-D® in combination with Septentrio dual-frequency GNSS receivers provides a global, seamless, high-accuracy position – often better than 10cm – at high updates rate that does not require local base stations, radios or cell coverage.

MARK YOUR CALENDAR

February 2013

Second High Level Forum on Global Geospatial Information Management
4-6 February
Doha, Qatar
http://ggim.un.org/

The International LiDAR Mapping Forum
11-13 February
Colorado, USA
www.lidarmap.org

ACSER
19 February
Sydney,Australia
www.acser.unsw.edu.au/oemf/workshop.html

March 2013

ASPRS 2013 Annual Conference
24 – 28 March
Baltimore, Maryland USA
www.asprs.org

April 2013

Annual World Bank Conference on Land and Poverty 2013
8 - 11 April
World Bank Headquarters, Washington, D.C., USA
www.landandpoverty.com

The Eighth National GIS Symposium in Saudi Arabia
15-17 April
Dammam, Saudi Arabia
www.saudigis.org/

7th Annual GNSS Vulnerabilities and Solutions Conference
18 - 20 April
Baska, Krk Island, Croatia
www.rin.org.uk

UN/Croatia Workshop on GNSS Applications
21 - 25 April
Baska, Krk Island, Croatia
www.unoosa.org/oosa/SAP/gnss/index.html

Pacific PNT
22-25 April 2013
Honolulu, Hawaii
www.ion.org

35th International Symposium on Remote Sensing of Environment
22 - 26 April
Beijing, China
http://www.isrse35.org

European Navigation Conference ENC 2013
23 -25 April
Vienna, Austria
www.enc2013.org

The 7th International Satellite Navigation Forum
24 – 27 April
Moscow, Russia
http://www.expocentr.ru/en/events/glon

May 2013

Intergeo East 2013
2 – 4 May
Istanbul, Turkey
http://www.intergeo-east.com/

The 8th International Symposium on Mobile Mapping Technology
1-3 May
National Cheng Kung University, Tainan
http://conf.ncku.edu.tw/mmt2013/

FIG Working Week 2013
6–10 May
Abuja, Nigeria
www.fig.net/fig2013/

The 4th China Satellite Navigation Conference
15-17 May
Wuhan, China
www.beidou.gov.cn

June 2013

Hexagon 2013
3- 6 June
Las Vegas, USA
http://www.hexagonmetrology.us

The Munich Satellite Navigation Summit 2013
18 – 20 June
Munich Germany
www.munich-satellite-navigation-summit.org

12th SEASC - Geospatial Cooperation towards a sustainable future
18 - 20 June
Manila, Philippines
www.seasc2013.org.ph

TransNav 2013
19 - 21 June
Gdynia, Poland
http://transnav2013.am.gdynia.pl

RIEGL LIDAR 2013 International User Conference
25 – 27 June
Vienna, Austria
www.riegllidar.com

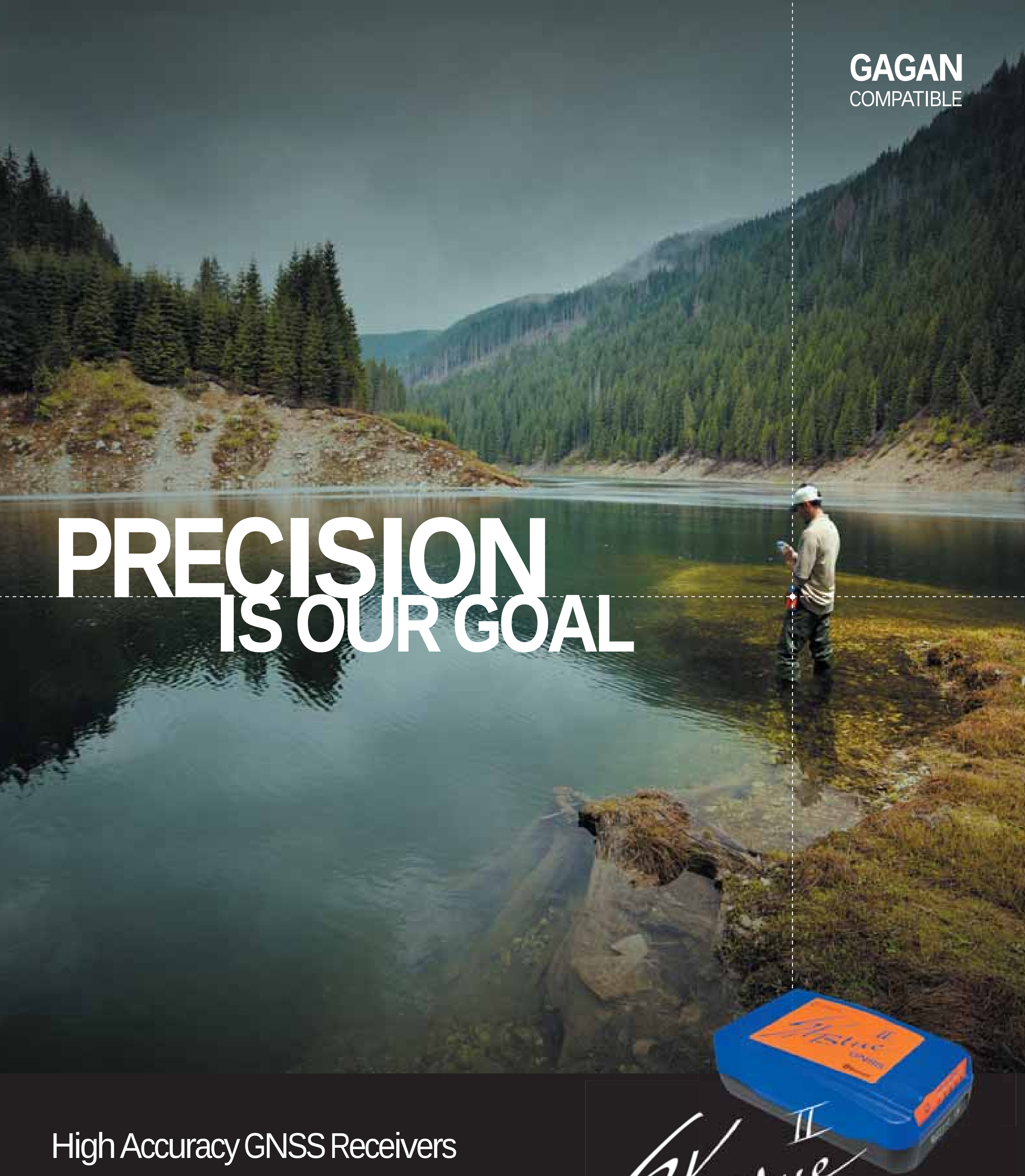
July 2013

GI Forum 2013
2 – 5 July
Salzburg, Austria
www.gi-forum.org

International Geoscience and Remote Sensing Symposium (IGARSS 2013)
22-26 July
Melbourne, Australia
www.igarss2013.org

August 2013

8th International Symposium on Digital Earth 2013 (ISDE 2013)
26-29 August
Kuching, Sarawak, Malaysia
http://isde2013.utm.my/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