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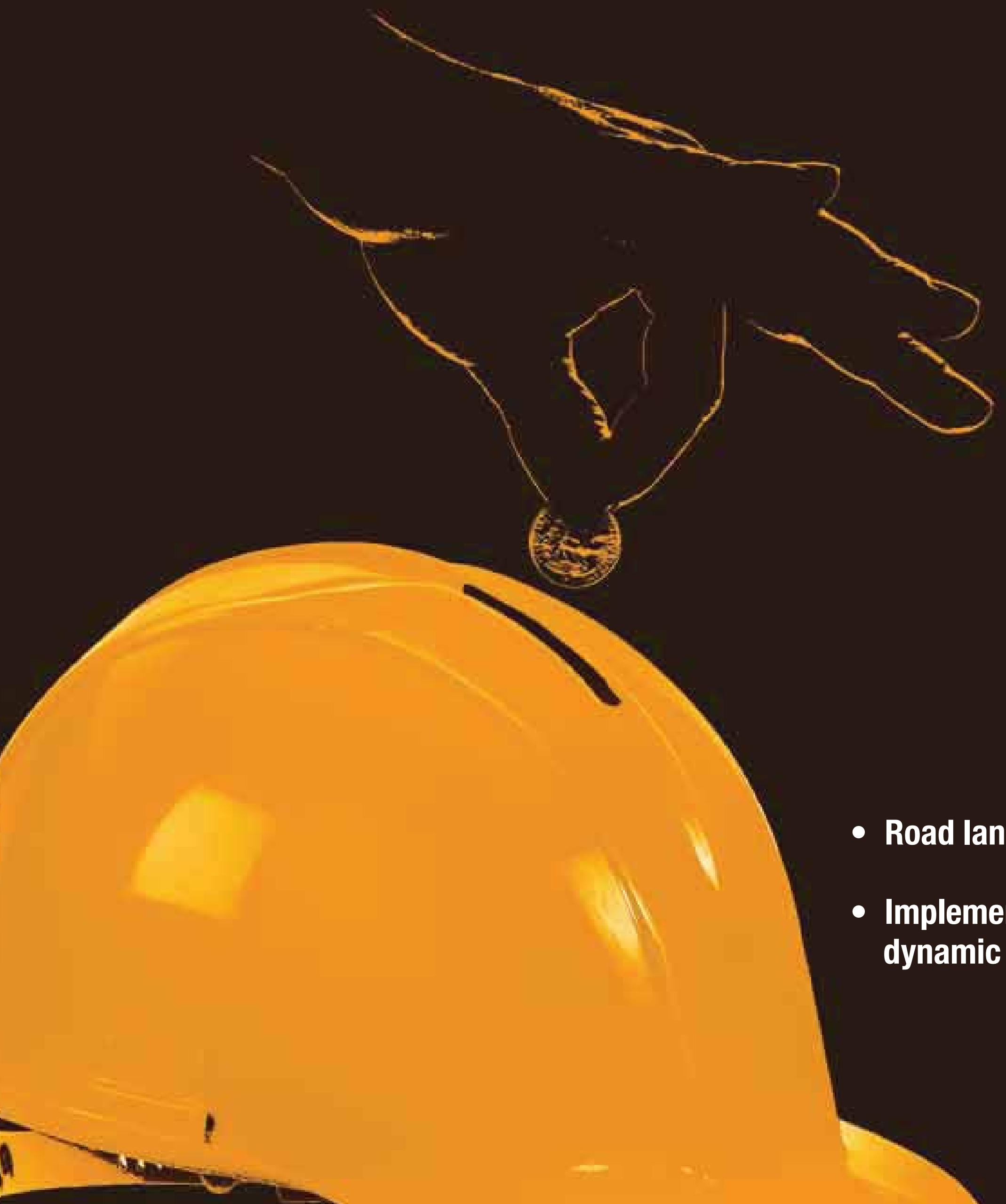
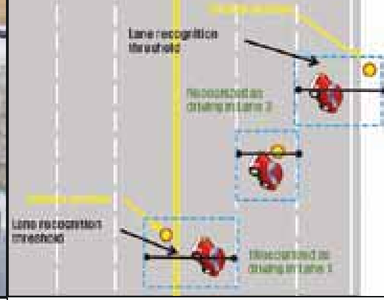
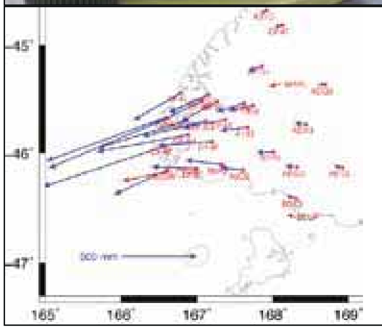
THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

Cost effective
GNSS positioning techniques



- **Road lane recognition**
- **Implementation of semi dynamic datum in New Zealand**



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Coordinates Volume 7, Issue 6, June 2011

Articles

Columns

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This issue of Coordinates is of 44 pages, including cover

States run show

Russia upholds ban on high resolution data.

China cracks down illegal mapping.

South Korea raids Google offices.

Demands in Pakistan to ban Google.

Such instances are reflections,

Of authority and control of the states,

And re-assertions that they call the shots,

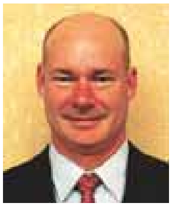
And will continue to do so,

Though not always for genuine reasons.

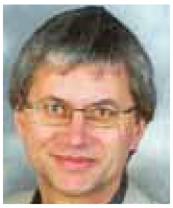
Bal Krishna, Editor
bal@mycoordinates.org

Cost effective GNSS positioning techniques

The main focus of the paper is to describe the use of emerging technologies in a cost-effective way and to illustrate the cost advantages of these technologies



Neil D Weston
Chief of the Spatial Reference System Division, National Geodetic Survey, NOAA.



Volker Schwieger
Professor and Director, Institute of Engineering Geodesy, University of Stuttgart (IIGS), Germany.

The first commercial GPS receivers were on the market in 1982. The receivers were large and bulky and could only track four satellites simultaneously. The satellites to track had to be selected manually on the receiver. Moreover, national geodetic agencies, research institutions and universities spent up to €250,000 for a single receiver. Today, modern receivers are much more sophisticated and can track GPS and GLONASS satellites simultaneously on more than 50 channels. Some of the latest receiver models can also track Galileo signals. Everything from satellite tracking to coordinate determination are computed automatically in real time. At the same time, costs of new receivers continue to decrease. A high-end geodetic quality GNSS receiver costs around €20,000. If a user is restricted to single-frequency, geodetic quality receivers, one would still have to spend €5,000 to €12,000. In general this does not pose a problem in developed countries, but it may be a drawback in developing countries or for tasks where the surveyor needs several receivers for specialized tasks such as monitoring.

In this contribution the authors will present several topics on the cost-effective use of GNSS. There are two possibilities to economize resources. The first pertains to a reference site or a network of reference stations and the second primarily concentrates on the rover or users side. For the first, we initially focus on Continuously Operating References Station (CORS) networks that provide the reference site(s) data and metadata to the users. For the second, the report proposes to use low-cost (under €150) GNSS receivers instead of high-end geodetic quality receivers. After giving an overview on GNSS and geodetic positioning, both approaches and their opportunities are presented. Finally, several cases on estimating the working costs will be developed and analyzed.

Cost-effective GNSS

Cost-Effective rovers / Low-rost GNSS receivers

Normal geodetic GNSS surveys are based on high-quality GNSS receivers and antennas. Frequently, the surveying community uses dual-frequency receivers to solve the ambiguities faster and more reliably. In the last few years, single-frequency receivers have proved to work very reliably if baseline lengths are below 10 km to 15 km. This opens up the market for receivers that are used for navigation since these receivers generally have a single frequency.

Table 1 compares the characteristics between navigation and geodetic quality receivers. In general navigation type receivers do not use the phase data. This problem is overcome by some manufactures where they provide access to the code and phase measurements from the raw via a serial or a USB interface. Some of manufacturers (e.g. u-blox) are officially documenting their format while others (e.g. Garmin) do not provide official format information or guarantee that the format will exist in the future.

For geodetic applications, highly precise antennas such as the micro-strip and choke rings are commonly used. They are constructed to reduce multipath effects and phase centre variations as well as type specific variations pertaining to the antenna phase centre offset. These choke ring antennas may cost up to €10,000. Sometimes the GNSS receiver and antenna are integrated as one unit. In contrast, many navigation type receivers integrate low-priced, simple antennas directly into their receiver box, while some receivers simply connect to an external antenna via a cable. In the latter case, the antenna may be fixed such as on the roof of a car using a magnet on the antenna casing. Portable antennas usually vary in price but start at several Euros. In general however, an antenna and a receiver are sold as a package. The quality of the performance of navigation type receivers can be improved if precise geodetic antennas are used. In this example, the cost-effectiveness is clearly reduced, so in this report the combination of navigation type receiver and navigation type antenna is mainly considered. The advantage of precise geodetic antennas can be reduced or even eliminated if the navigation type antennas are calibrated. Figure 5 shows an example for the u-blox ANN-MS antenna (in combination with the u-blox LEA 4T receiver). Additionally, the navigation antennas need the capability of being leveled and centered. Some experiments show that metal ground plates often reduce multipath effects, especially when metal reflectors such as a car roof are nearby.

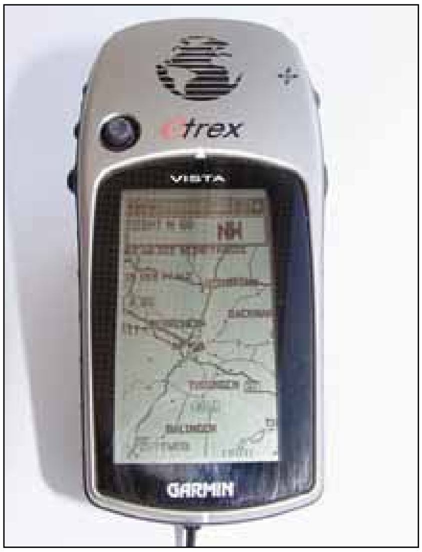


Fig. 1: Garmin eTrex Vista (raw phase data available, format not documented)

Fig. 2: u-blox Lea-4T receiver (raw phase data available, format documented)

Fig. 3: High precision choke ring antenna (source: Leica Geosystems)

In the following section, an overview on low-cost receiver-antenna combinations is given. The entries in the table are given as an example, mainly because the content and number of combinations in the table will change rapidly in the future. The overview is restricted to exemplary Garmin and u-blox receivers for prices up to €150 for a receiver-antenna combination.

The accuracy of coordinates determined by low-cost receivers is very similar to those obtained from geodetic type receivers. Hill et al. (2001) reports standard deviations below the decimeter level for Garmin receivers. Schwieger documents accuracies around 2 cm for baselines up to 1.1 km using a Garmin eTrex receiver (Schwieger, 2007 and Schwieger & Wanninger, 2006) and below 2 cm for baselines up to 7 km using a u-blox AEK-4T receiver (Schwieger, 2009) with observation times between 20 and 30 minutes. Abidin & Muchlas (2005) obtain standard deviations below 20 cm for baselines up to 100 km in length with 20 minutes occupation time. In conclusion, the accuracy is not equivalent to single or dual-frequency geodetic receivers but for many surveying applications the level is sufficient.

Continuously Operating Reference Station (CORS) Networks

Introduction

In 1994, William E. Strange, the Chief Geodesist of the National Geodetic Survey, was the first individual who defined the term Continuously Operating Reference Station (CORS) as a permanently installed geodetic quality receiver and antenna positioned over a monument or point which collected GPS data 24 hours a day, every day of the year. The initial idea was to establish a network of CORS so users could use data from any of the permanent stations with their own GPS equipment. CORS networks typically have GNSS receivers that provide carrier phase and code range measurements in support of 3-dimensional positioning activities. Today there are numerous CORS networks that have been established throughout the world to support an unlimited number of applications.

Engineers, surveyors, GIS/LIS professionals, scientists and others can apply CORS data to position points at which GNSS data have been collected as well as using the data to model a number of physical systems. A CORS system enables positioning accuracies that approach a centimeter or better relative to a worldwide network, such as the ITRF or to a local network such as the NAD83 in the United States. CORS systems benefit from a multi-purpose cooperative endeavor involving numerous governmental, academic, commercial and private organizations. As an example, the diagrams shown below illustrate the agencies and sectors that participate in the National CORS network of the United States.

CORS Station Configuration

The size and complexity of a CORS network varies considerably and therefore one station design cannot address all configurations. However, the following areas should be considered when planning new CORS or expanding an existing network. GNSS receivers should be

Receiver Class	Signal Used	Applications	Accuracy	Costs
Navigation	code or phase-smoothed code, one frequency	car navigation, location based services, sailing, mass market	1 to 10 m	5 – 100
Geodetic	code and phase, in general two frequencies	surveying, geodesy, geodynamics	0.001 to 0.1 m	10,000 – 30,000

Tab. 1: Characteristics of geodetic and navigation GNSS

able to track multiple constellations such as simultaneously collecting data from the GPS and GLONASS systems. The receiver should also use a geodetic quality antenna, preferably one that minimizes multipath and is mounted to a pillar or other stable structure. For remote installations, an enclosure to house power supplies, batteries, a computer and telecommunications equipment is strongly suggested. If the CORS station is part of a mission-critical program such as the Wide Area Augmentation System (WAAS) offered by the Federal Aviation Administration (FAA), then installing multiple receivers at a location is worth considering. The following figure 7 depicts a typical CORS installation from the Plate Boundary Observatory (PBO) in the Western United States.

Products from a CORS Network

For large CORS networks, the design may include regional data centers for quality checking, processing, distributing and archiving GNSS data. Most networks around the world collect and disseminate GNSS data 24 hours a day as well as offering other services and IGS products such as broadcast and precise ephemeris and clock information for post processing.

There are also an increasing number of data centres which offer real time RTCM-104 format data streams using the Networked Transport of RTCM via Internet Protocol (Ntrip). Ntrip is an open protocol based on the Hypertext Transfer Protocol HTTP/1.1 and has many advantages such as having the ability to stream any kind of GNSS data, disseminating numerous streams simultaneously and can be used over mobile IP networks using TCP/IP. Data centers that offer RTCM or real time data streams usually have a server known as an NtripCaster that listens for requests from users NtripClients for one or more data streams. The data streams are then used to support stationary or mobile applications such as rapid static and kinematic surveys, hydrography, LIS/GIS development and vehicle navigation. These types of data centers will play a more significant role as the need for faster and more readily available GNSS information is desired.

Web-based tools

The rapid and automated uses of CORS networks are implemented in many post-processing services. In this case, a user does not need to worry about the processing tasks involved. A user sends their data, usually in RINEX format, to the service provider, a solution is computed and the estimated coordinates are sent to the user via email. In the following sections four different services that are currently available for use are mentioned:

Online Positioning User Service – OPUS: OPUS from the National Geodetic Survey is a web-based service to provide GPS users with an easy method to submit and process their data in an accurate and reliable fashion. The end products are two sets of geodetic coordinates having a precision of about 1.0 cm and are consistent with the latest ITRF coordinate system and the National Spatial Reference System (NSRS) of the United States.

Scripps Coordinate Update Tool – SCOUT: The Scripps Coordinate Update Tool (SCOUT) is also a web-based geodetic tool that can be used to compute a set of coordinates for a station.

AUSLIG's Online GPS Processing Service – AUSPOS: AUSPOS is also a web-based positioning utility which provides users the ability to submit GPS data to a processing system. This free service accepts static, dual frequency, geodetic quality data and makes use of the Geocentric Datum of Australia (GDA) and the International Terrestrial Reference Frame (ITRF).

Canadian Spatial Reference System Online Global GPS Processing Service – CSRS-PPP: Natural Resources Canada (NRCan) provides a Precise Point Positioning (PPP) service through the web which can compute highly accurate positions from raw GPS observation data in a post-processing mode. The PPP system uses precise IGS orbit

Fig. 4: Low-price u-blox ANN-MS antenna with adapter

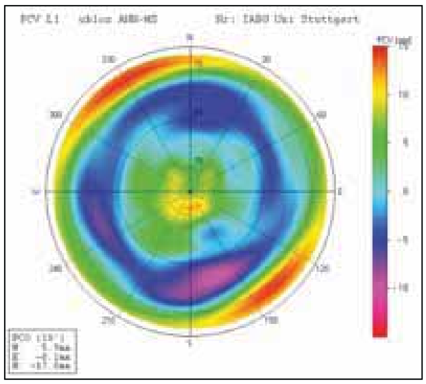


Fig. 5: Antenna pattern for u-blox ANN-MS antenna

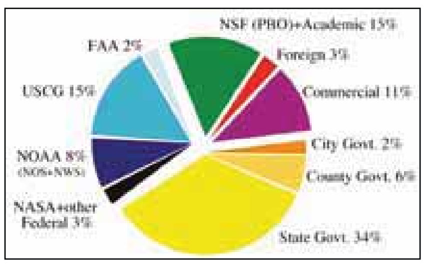


Fig 6: Federal, state, local, commercial and academic participants of the CORS network in the United States

Manufacturer	Receiver	Format	App. Price
U-Blox	Aek-4T	Ubx Format, Documented	145 $
U-Blox	Aek-5T, Firmware 6.00	Ubx Format, Documented, Premium Option	145 $
Garmin	Etrex H	Garmin Binary, Not Documented	99 $
Garmin	Gps 18	Garmin Binary, Documented	75 $

Tab. 2: Overview on low-cost GNSS receivers with available phase data

and clock information and can accept static or kinematic data from either single or dual frequency receivers.

Cost-effectiveness

The estimation of the financial benefit is described in this section. This benefit cannot be 100% correct since the labor costs are quite different in most countries. For this reason, approximated values and intervals are introduced and shown in the following figures. We use an interval from €1 (lowest level, developing countries) to €70 (developed countries) to get a rough estimation.

As a variant 1, the benefit of a using a CORS reference station network is presented. For this variant, the surveyor economizes the financial resources to be spent for the receiver at the reference site and for one person to assemble and care for the reference receiver during the measurement stage of the survey. Geodetic dual-frequency receivers having a price of €20,000 are used for the comparison. It is assumed that a receiver can be used for three years and would therefore give a €6,666 per year operational cost. Two variants could be investigated. The first is when the service is free of charge and the second is when you have to pay for it. For the second case an interval from €500 up to €3,000 per year as possible

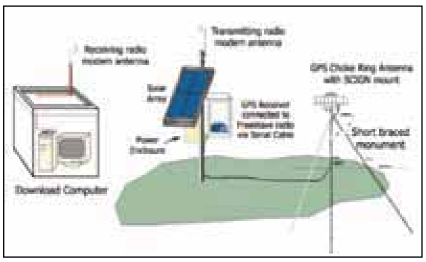


Fig 7: Typical CORS station configuration for the Plate Boundary Observatory (PBO) network. Courtesy UNAVCO, CO.

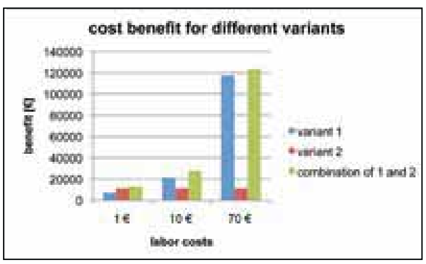


Fig. 8: Benefit of the different cost-effective techniques

flat rates may be considered. The authors assume a flat rate of €1,000 per year.

The second benefit is achieved when low-cost receivers are used for data acquisition (variant 2). In this case, the amount for the rover and the reference receiver is reduced significantly, usually between €20,000 to approximately €100. The labor costs do not change, but there may be additional costs such as for two laptop computers or data loggers (overall approximately €2,000 in 3 years) have to be considered. Software is an additional expense and is available for €1,000.

The third possibility is the combination of both, the use of low-cost receivers with a CORS network Figure 8 illustrates the benefits of the different variants with respect to the GNSS without cost reduction for three labor cost levels (€1, €10 and €70). The benefits and cost savings in using a CORS station or network is important in many cases, but for developed countries it is most beneficial because labor costs are high and these are the ones to be optimized in this variant. Variant 2 is most important for very low labor costs but becomes less attractive with increasing labor costs, especially when they are given as a percentage. The benefit is further improved for the combination of both variants.

Concluding remarks

FIG Commission 5 - Positioning and Measurement would like to emphasize that there are many possibilities when performing static and kinematic surveys and are encouraged by the results delivered by current GNSS positioning technologies. The reliability, promptness and accuracy of the hardware and techniques will continue to increase in the future, especially when the number of available satellites continues to grow from year to year.

The main focus of the report was to describe the use of this emerging technology in a cost-effective way and to illustrate the cost advantages of these technologies. The advantages shown will hopefully encourage surveyors all over the world to establish cost-effective surveying practices using GNSS positioning within their profession.

Acknowledgement

This contribution is a short version of the official FIG Commission 5 publication No 5 (Weston & Schwieger 2010). It is available through: http://www.fig.net/pub/figpub/pub49/figpub49.pdf.

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Weston, N.D., Schwieger, V. (2010): Cost Effective GNSS Positioning Techniques. FIG Publication No 49, FIG Commission 5 Publication. The International Federation of Surveyors, Copenhagen, Denmark, 2010.

Our customers can establish a successful business by flying an UltraCam

Says, Mr. Alexander Wiechert , Business Director, Vexcel Imaging GmbH in coversation with Coordinates

What are the high points in the journey from the UltraCam photogrammetric digital aerial mapping camera introduced in 2004 to recently announce of a new version of the UltraMap workflow software UltraMap 2.2?

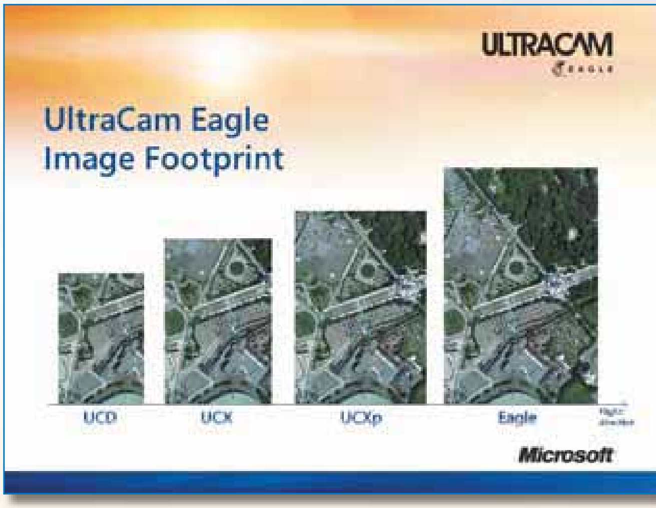
The UltraCam was conceived by Vexcel Imaging prior to the acquisition of the company by Microsoft. The organization, now known as the Microsoft UltraCam product group, has a history of leading the industry by innovation. We presented the UltraCamD in 2003/2004 which led to the innovation of the UltraCamX in 2006, and the UltraCamXp and UltraCamXp Wide Angle in the 2008/2009 timeframe. For the smaller footprint camera market, we released the UltraCamL in 2008 and then evolved this to the UltraCamLp in 2010. Recently, in May 2011, we announced the next revolutionary photogrammetric camera system: the UltraCam Eagle.

Our UltraMap processing software has undergone a similarly, if not even more radical, significant evolution. The acquisition of Vexcel Imaging by Microsoft has allowed the UltraCam team access to a huge amount of cutting edge software developed by the R&D centers of Microsoft. Some of the innovative features of UltraMap now include automated distributed processing, monolithic geometry, monolithic radiometry, automated hotspot removal, haze and sun angle correction and automated project based color balancing. This all makes image processing faster, reduces manual interaction to the absolute minimum and provides superior quality in the end image product.

UltraCam Eagle represents a revolution in digital photogrammetric camera systems. Please explain.

The time was right for another revolutionary step with the UltraCam. The UltraCam Eagle opens up a completely new camera classification in the aerial camera segment: the “ultra-large” format camera system of more than 20,000 pixels across the flight strip. The enhancements from prior UltraCam systems are extensive: we developed new CCDs with an industry leading signal to noise ratio of 72 dB; we developed a new optimized lens system at the cutting edge of today’s lens technology; and we developed new camera electronics. These enhancements ensure best-in-class image sharpness and dynamics – extremely important for aerial survey and photogrammetry.

Furthermore, we adapted our monolithic geometry and radiometry features of UltraMap to support the UltraCam Eagle. We developed an exchangeable lens system that allows lens exchange without recalibration, while still maintaining the sub-pixel accuracy. We established unprecedented system integration through a modular housing concept that incorporates an in-flight, exchangeable solid-state storage that is capable of storing over 3800 images and an optional GPS/INS/FMS system fully embedded in the sensor head. We reduced the camera weight and power consumption by 50%. All this maximizes camera operation, flexibility and reliability and, at the end of the day, allows the camera user to capture more, higher quality data with fewer costs.



Is pricing a consideration while evolving the marketing strategies, especially in the developing world?

Yes, sure. Price is always a consideration. That is why we developed such a broad range of camera systems ranging from the UltraCamLp to the UltraCamXp to the UltraCam Eagle. Each of these cameras has a specific price point that reflects the performance and market segment. But all are based on the award-winning UltraCam multi-cone concept for maximum camera reliability and image quality. This allows customers to choose the UltraCam system that best fits their budget, business and operation, and always be sure that their organizations are delivering the high standard of UltraCam quality to their customers.

What makes your products and solutions unique in the industry?

There is no sole reason, rather it is due to a combination of factors such as the outstanding performance/price ratio of the system driven by strong innovation; the camera design principle based on multi-cones and software leveraged hardware; the outstanding processing software UltraMap; the strong commitment to customer satisfaction and customer service, including a comprehensive camera upgrade program. And last but not least: an experienced, skilled and motivated world-class UltraCam team that works extremely hard every day to make the best cameras and software and to deliver the best service to the customer; and our knowledgeable sales and support partners around the globe.

Last couple of years has seen a surge in demand for your camera’s across the globe. How that was achieved?

The market has decided. We estimate that today little more than 400 digital photogrammetric cameras have been sold world-wide and that more than 300 of those are frame-based cameras. This is strong indication that the market has chosen frame cameras as the preferred concept. As of May 2011, 195 of these more than 300 photogrammetric frame cameras are UltraCam cameras. This gives us a 48% global market share of all digital photogrammetric cameras and a 65% market share of all digital photogrammetric frame cameras. Currently over 65% of all cameras sold annually are UltraCams. Why did this happen? Why are we continuously gaining market share? We believe that it’s because, at the end of the day, our customers know that they can establish a successful business and win in their markets by flying an UltraCam rather than another camera.

The **UltraCam Eagle** combines legacy with innovation. Built on award-winning UltraCam technology, this latest breed of digital aerial sensor revolutionizes the market with enhancements for precise imagery at unprecedented efficiencies.

With an ultra-large image footprint spanning over 20,000 pixels, the UltraCam Eagle will take your projects to new heights of quality and efficiency. The total system weight has been trimmed by 50 percent, helping you reduce fuel consumption with each mission. Flying fewer flight lines and spending less on fuel, you will be able to capture breathtaking imagery more efficiently than ever before.

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Road lane recognition

A precise digital map is needed to perform lane recognition using carrier-based GNSS position information

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Senior Researcher
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The economic development of the past half century has transformed peoples' way of life. In the field of transportation, the use of private cars to facilitate personal travel has increased exponentially. However, this increase is causing an array of problems, such as traffic congestion, environmental pollution and car accidents, which in turn has led to a rise not only in human and material loss but also in social and economic costs [1]. In response, advanced nations like the US, those of the EU and Japan are dealing with the ever-growing transportation demand by adopting Intelligent Transportation Systems (ITS) [2,3].

To enable the efficient operation of ITS, it is necessary to collect location data for vehicles on the road. In the case of futuristic transportation systems such as the project known as the Ubiquitous Transportation and Smart Highway, a method of data collection that is advanced enough to incorporate road lane recognition is required. To meet this requirement, technology based on Radio Frequency Identification (RFID) has been researched. However, RFID may fail to yield installing tags across all roads, which necessarily incurs an enormous cost.

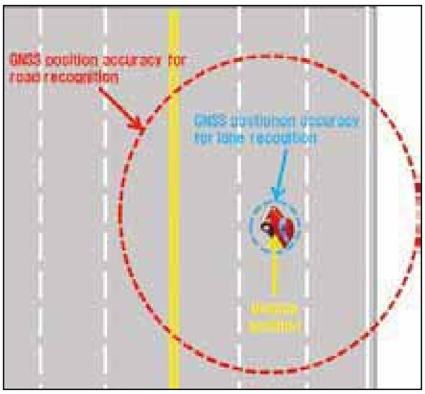

Fig. 1. Digital map for automotive vehicles

Fig. 2. Digital map for automotive vehicles

One cost-saving alternative currently being researched is to utilize Global Navigation Satellite System (GNSS) carrier-based location information where available [4]. For lane recognition using GNSS, a precise digital map to determine the vehicle position by lane is needed. A "precise digital map" is a map containing the location information of each road lane to enable lane recognition. Therefore, this study analyzes the performance requirements of a precise digital map capable of lane recognition based on the accuracy of GNSS location information and a precise digital map. In addition, the road lane recognition system is tested on an actual road to verify the possibility of lane recognition using GNSS and a precise digital map.

Characteristics of the precise digital map

Precise digital maps have characteristics similar to those of the digital maps currently being used for vehicle navigation. However, because they must show lane information for the driver using carrier-based GNSS data, they differ from regular digital maps, as shown in Table 1. The purpose of currently available vehicle navigation system is to provide route information to the driver's destination. To this end, the digital maps used in vehicle navigation systems are produced by building a database of the geometric alignment of the roads. The vehicle location is marked on a digital map using a method known as map

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esri

matching. Hence, in digital maps, the road serves as the reference for identifying the vehicle location, and the centerline of the road becomes the reference for marking the vehicle location, as shown in Fig. 1.

In contrast, a vehicle navigation system, capable of lane recognition, has the dual purpose of providing route information to the destination and furnishing information about relevant road lanes. Therefore, it must store information about not only the geometric alignment of the roads but also the alignment of each road lane. In this instance, the center line of the road lane, which allows differentiation among the various lanes, serves as the reference for distinguishing the vehicle's location. Thus, in order to mark the vehicle's drive position according to the road lane, vehicle position marking information with a level of accuracy that allows for lane differentiation is needed. Vehicle navigation systems in current use calculate the vehicle location through the standalone use of code-based GNSS signals. When using a code to calculate the position of the vehicle, the resulting degree of accuracy is approximately 15 m (2D RMS), as shown in Table 2.

However, to differentiate road lanes, vehicle location data that has a level of accuracy greater than the width of the lane is necessary. This means that carrier-based GNSS location data, which has an accuracy of less than several dozen cm, is needed. Because this enhances the accuracy of the location information used to mark the vehicle position over existing digital maps, the location accuracy of the map itself must also be enhanced over that of existing digital maps.

Category	Digital map	Precise digital map
Reference for determining the vehicle location	Road (Road centerline)	Lane (Lane center line)
Information for marking the vehicle location	GNSS code-based location information	GNSS carrier-based location information
Degree of location accuracy	1 m or more	1 m or less

Table 1. A digital map vs a precise digital map

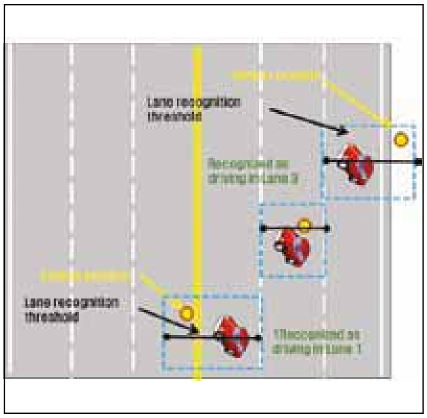

Fig. 3. The conditions for road lane recognition

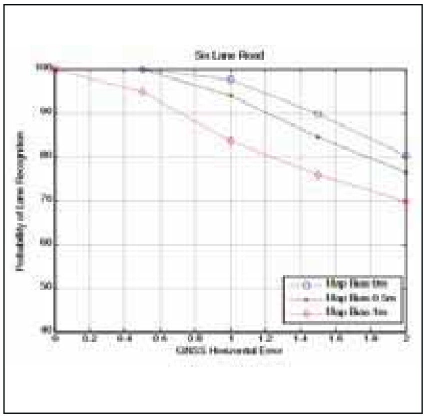

Fig. 5. Analysis results for a six-lane road

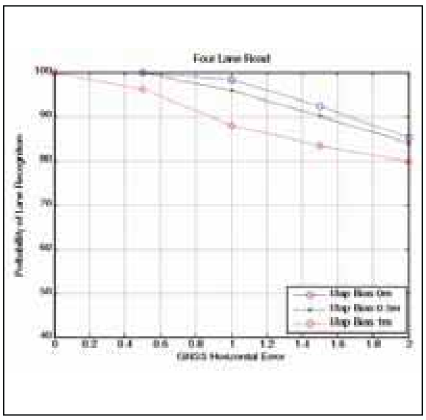

Fig. 4. Analysis results for a four-lane road

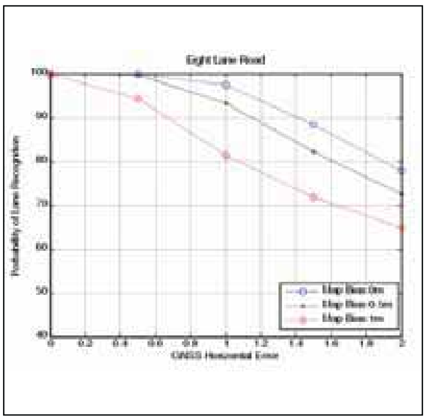

Fig. 6. Analysis results for an eight-lane road

Digital maps are produced by converting a numerical map based on aerial photogrammetry into digital information for use on a computer or a similar device. The location information for structures such as roads or buildings contained within a digital map is assigned through control point surveys and aerial triangulation during aerial photogrammetry. The location error produced at this stage of the process becomes the location error present in the digital map. At present, digital maps are created on 1:1000 scale numerical maps; they are known to have an error of 1 m or more. When actual road driving results calculated using a commercial RTK program (Way Point) are marked on a digital map, the position of the vehicle apparently deviates from the road due to map error, as shown in Fig. 2. Therefore, a precise digital map must be made to coincide more closely with the actual geographical location of road lanes compared to existing digital maps.

Performance analysis of the precise digital map

Performance analysis of precise digital maps test whether a vehicle calculating its position using GNSS carrier-based location data can recognize the actual drive lane while driving in different lanes. The lane recognition results are expressed as lane recognition success rates. The conditions of the analysis assume a vehicle driving along the center line of a lane measuring 3 m in width on a bidirectional four-lane, six-lane or eight-lane road with the precise digital map position bias and GNSS position error listed in Table 3.

In the case of GNSS error, carrier-based positioning can achieve an accuracy of within several mm, in theory. However, this assumes a favorable and static signal reception environment. In an actual road driving situation, surrounding buildings, roadside trees, and other features cause multipath error and reduced visibility, thus compromising position accuracy. Therefore, the accuracy of carrier-based GNSS position information is considered for the range of 0.5 m to 2 m. In the case of the precise digital map, the error characteristics of the linearization point

are reflected in the configuration of the coordinates for other points during the process of linearization; thus, the error characteristics can be seen as a type of bias.

The lane recognition threshold is the threshold that allows a lane to be correctly identified when the vehicle is assumed to be driving along the center of the lane; its value is thus proportional to the width of the lane. The lane recognition threshold for each lane of the map bias to the right of the drive direction is shown in Eqs. (1)-(3). A vehicle whose position information was calculated as being over the centerline and in the oncoming lane is still counted as being in the innermost lane (Lane 1), as shown in Fig. 3. Similarly, a vehicle whose position was calculated as being off the road and on the sidewalk is still counted as being in the outermost lane (Lane n).

Signal type	Method	Accuracy (m, 2D RMS)
Code	Standalone	15
	Differential	5
Carrier	Standalone	-
	Differential	0.3

Table 2. The performance of GNSS

Bias of the precise digital map (m)	Horizontal position error of GNSS (2D RMS)
0	0.5, 1, 1.5, 2
0.5	0.5, 1, 1.5, 2
1	0.5, 1, 1.5, 2

Table 3. Error specifications

$$\infty < Threshold_1 \le \frac{W_{lane}+P_{Ant}}{2} - B^+_{emap} \quad (1)$$

$$\frac{W_{lane}-P_{Ant}}{2} - B^+_{emap} < Threshold_{2\sim n-1} \le \frac{W_{lane}+P_{Ant}}{2} \quad (2)$$

$$\frac{W_{lane}-P_{Ant}}{2} - B^+_{emap} < Threshold_n \le \infty \quad (3)$$

Here, B^+_{emap} is the map bias to the right of the drive direction and B^+_{emap} is that of the left of the drive direction. In addition, $Threshold_n$ is the lane recognition threshold of each lane, W_{lane} is the lane width and P_{Ant} is the partiality (right = positive) of the antenna from the center of the vehicle.

For 95% lane recognition, the GNSS horizontal position error must be within 1.2 m when the map bias is 0 m; within 0.8 m when the map bias is 0.5 m; and within 0.4 m when the map bias is 1 m, as shown in Figs. 4~6. Therefore, when performing lane recognition using position information with a horizontal position accuracy of 1 m or less, a precise digital map with a bias of within 0.25 m is needed.

Lane recognition test

To verify the possibility of lane recognition using GNSS and a precise digital map, we performed actual road tests. The test site was Ochang, Chungbuk, in Korea, as show in Fig. 7. We developed a road lane recognition system consisting of a carrier-based GNSS receiver that included a precise positioning algorithm and a unique lane-level digital roadway database. We also developed a precise digital map to suit the performance requirement. To verify the accurate performance of the test, we drove while staying in one lane. We performed the test by traveling in different lanes as well.

The test results show the possibility of recognizing the road lane using CDGPS and a precise digital map, as shown in Fig. 8. The red line is the vehicle position as calculated by the carrier-based GNSS algorithm, the yellow line is center of the road, and the white line is the lane.

Fig. 7. The test site (circle in the red box)

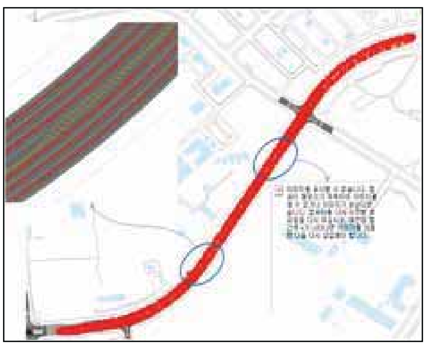

Fig. 8. Experiment of road lane recognition

Conclusion

A precise digital map is needed to perform lane recognition using carrier-based GNSS position information, as demanded by the requirements of futuristic transportation systems. Precise digital maps differ from the digital maps used in conventional vehicle navigation systems in terms of their vehicle position reference, the accuracy of the position information used and their map position accuracy. This study analyzed the performance requirements of precise digital maps using the above mentioned characteristics in addition to the GNSS position error for vehicles on the road. To verify the possibility of lane recognition using GNSS and a precise digital map, a car driving test was conducted on an actual real road.

The analysis of the results confirmed that the achievement of a 95% lane recognition success rate using GNSS information requires less than 0.8m accuracy with a precise digital map. This was determined by car driving test that was conducted on an actual road. The results show the possibility of recognizing a road lane using GNSS and a precise digital map.

Acknowledgements

Support for this study was provided by Development of GNSS-based Transportation Technology of the Ministry of Land, Transportation and Maritime Affairs, Korea.

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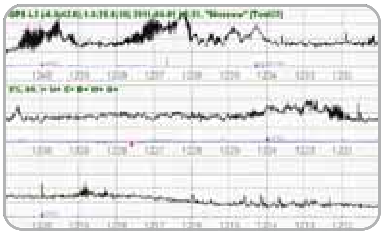


Question 1

TRIUMPH-VS has 216 channels. The spectrum analyzer feature of TRIUMPH-VS scans GNSS bands and shows the presence of jammers and interferences using:

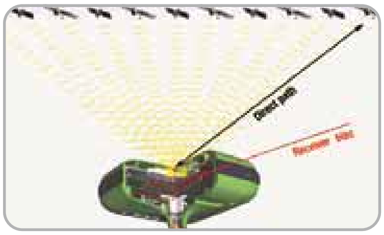
A	60 channels for jammer detection while normal satellite tracking continues using the remaining 156 channels.	○
B	60 channels for jammer detection but normal satellite tracking stops during jammer detection.	○
C	10 channels for jammer detection while normal satellite tracking continues using the remaining 206 channels.	○
D	216 channels for jammer detection and normal satellite tracking stops during jammer detection.	○
E	108 channels for jammer detection and 108 channels for normal satellite tracking.	○
F	3 channels for each band for jammer detection and the remaining channels for normal satellite tracking.	○

Question 2

A commercially available $430 GJ6 jammer can:

A	Completely knock out all GPS bands and significantly damage GLONASS bands.	○
B	Completely knock out all GLONASS bands and significantly damage GPS bands.	○
C	Completely knock out all GPS L2 and GLONASS L1 bands.	○
D	Completely knock out only GPS and GLONASS satellites that are in its direct line of sight.	○
E	Completely knock out all P-Codes with minimal affect on C/A codes.	○
F	Create huge amount of multipath in all GPS and GLONASS bands.	○

Visit www.javad.com website and enter your answers.



Question 3

GLONASS signal quality in JAVAD GNSS receivers is as good as GPS because we dynamically remove the effects of GLONASS inter-channel biases with the accuracy of:

A	Better than 2 meters.	○
B	Better than 20 centimeters.	○
C	Better than 2 centimeters.	○
D	Better than 2 millimeters.	○
E	Better than 0.2 millimeters.	○
F	Better than 20 microns.	○

Question 4

Superior performance of JAVAD GNSS six-pack RTK V6 engine is achieved by:

A	Assigning 3 engines to GPS and 3 engines to GLONASS.	○
B	Randomly assigning satellites to each engine.	○
C	Engines operating sequentially to obtain the best combination.	○
D	All engines operating simultaneously but each with a different algorithm and their weighted averages providing the final RTK solution.	○
E	All engines operating with the identical algorithm and their sum providing much better results.	○
F	Engines being divided between GPS and GLONASS satellites according to the relative number of visible satellites of each system.	○

Visit www.javad.com website and enter your answers.

Question 5

You can assemble points in your computer and transfer them to the TRIUMPH-VS for stakeout (or other purposes) and get points back to your computer using the following JAVAD GNSS software:

- **A** JustinLink.
- **B** Giodis.
- **C** NetView.
- **D** NetHub.
- **E** SteakWare.
- **F** Tri-VU.

Question 6

To create your own local coordinate systems in the TRIUMPH-VS do the following:

- **A** Have your local points in one layer and surveyed points in another layer of the current map and click localize.
- **B** Have each local point together with its corresponding surveyed point in a layer of the current map and click localize. 10 layers support up to 10-point localization.
- **C** Have your local points and surveyed points in the same layer, but identify them with "L" and "S" prefixes and click localize.
- **D** Have your local and surveyed points in any layer but provide a matrix to show their relationships and click localize.
- **E** Have your local and surveyed points in "Localize" matrix and click localize.
- **F** Have your local points in the "Local" map and surveyed points in "Survey" map and click localize.

Visit www.javad.com website and enter your answers.

Question 7

The TRIUMPH-VS contains all you need to perform RTK survey using VRS (Virtual Reference Station) or RTN (Real Time Network). In addition to Wi-Fi, LAN, and GPRS, it also supports the "Edge" connection. Compared to Standard GPRS, Edge is an advanced and special GPRS protocol that is:

- **A** More secure but slower.
- **B** Slower but less expensive.
- **C** Much faster.
- **D** Same speed but less expensive.
- **E** Same speed but more secure.
- **F** Same speed but uses much less power which saves battery life significantly.

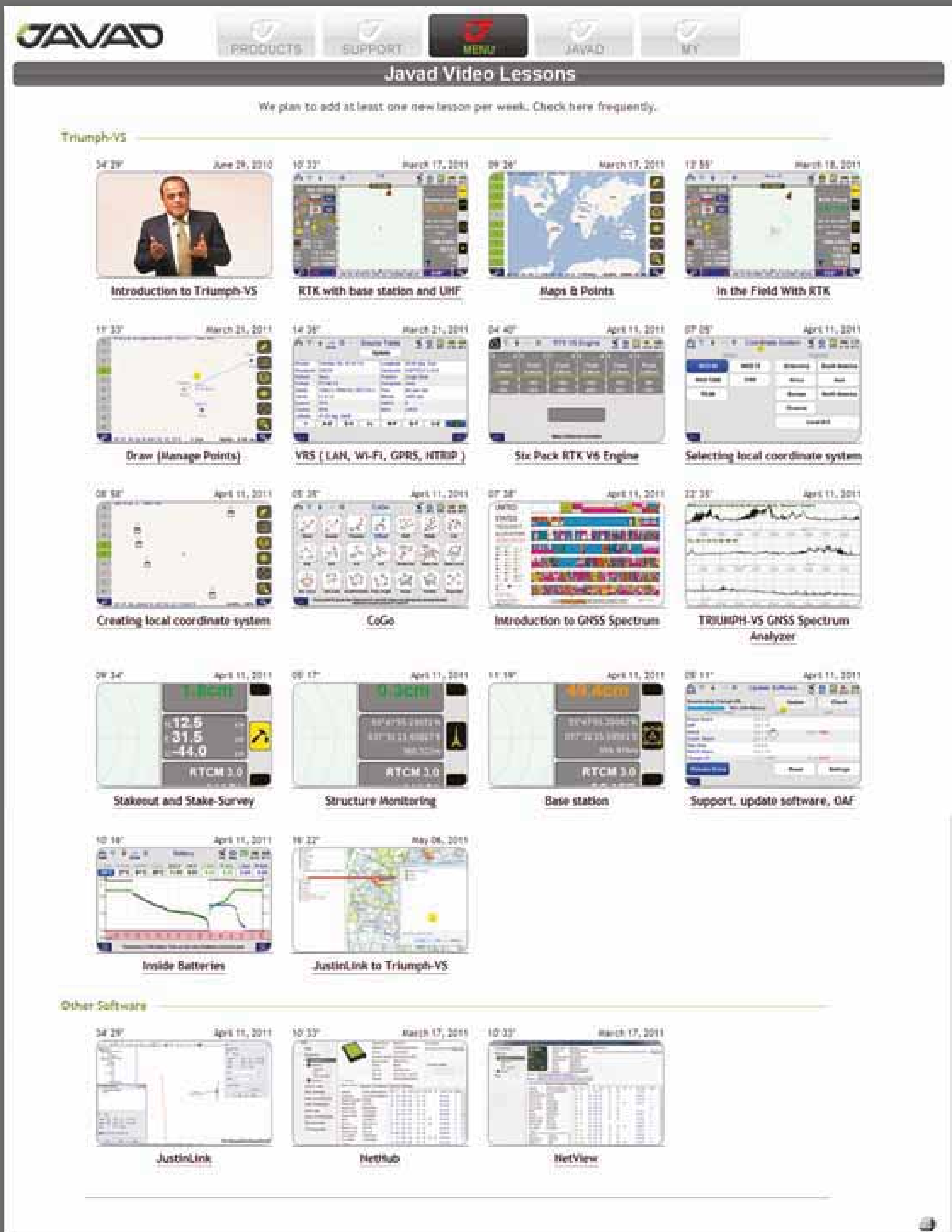
Question 8

We continue to improve TRIUMPH-VS software. To update all TRIUMPH-VS software components to the latest version you must:

- **A** Download updates from www.javad.com to computer and then transfer to TRIUMPH-VS using Windows Mobile Device Center or Active Sync.
- **B** Download updates from www.javad.com to computer and then transfer to TRIUMPH-VS using JustinLink software.
- **C** Download updates from www.javad.com to computer and TRIUMPH-VS will take them automatically.
- **D** Download updates from www.javad.com to computer and transfer to TRIUMPH-VS using NetHub.
- **E** Connect the TRIUMPH-VS directly to the Internet (LAN, Wi-Fi, or GPRS) . On the "Software Update" screen click "Update". Decide which software versions you want to update and click "Download".
- **F** Connect the TRIUMPH-VS directly to the Internet (LAN, Wi-Fi, or GPRS). On the "Software Update" screen click "Update".

Visit www.javad.com website and enter your answers.

www.javad.com
Video Lessons



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Implementation of semi dynamic datum in New Zealand

The use of a semi dynamic datum has been well accepted. Its implementation and use have been relatively straight forward from a technical and geodetic perspective

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Don Grant
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New Zealand lies across the obliquely convergent Australian and Pacific plate boundary. To the northeast of New Zealand the Pacific plate is subducted beneath the Australian plate and to the southwest of New Zealand the Australian plate is subducted beneath the Pacific plate resulting in a combination of strike slip and uplift motion with horizontal motions of 40-55mm/yr along the plate boundary (Walcott 1984). In addition to the plate motions, New Zealand experiences the effects of other deformation events such as large earthquakes, volcanic activity, and more localised effects such as landslides.

In 1998 LINZ implemented a new geocentric datum, New Zealand Geodetic Datum 2000 (NZGD2000) with a reference epoch of 1 January 2000 (2000.0) to address inaccuracies in the previous datum (NZGD49) as well as datum degradation over time due to crustal deformation.

NZGD2000 is realised in terms of ITRF96 and uses the GRS80 ellipsoid (Grant et al 1999). NZGD2000 was defined to be a semi-dynamic datum where coordinates remain fixed at a reference epoch, however the inclusion of a deformation model enables:

- coordinates to be generated at the reference epoch from observations made at a time other than the reference epoch; and
- coordinates or calculated vectors between points to be generated from the reference epoch coordinates at a time other than the reference epoch.

This is achieved by incorporating a national horizontal deformation model (Fig. 1) to model the estimated (predicted) effects of crustal deformation.

NZGD2000 coordinates at the datum reference epoch of 2000.0 are determined by applying the deformation model when generating new coordinates (Fig. 2). The current deformation model uses a constant horizontal deformation velocity through time and assumes zero vertical deformation.

In the case of localised deformation events such as earthquakes or landslides, it has been proposed that these are modelled independently of the national deformation model, and then added to the deformation model as a localised patch (Blick et al 2003).

What has gone well with the implementation of NZGD2000

The implementation of a semi-dynamic datum with the inclusion of a deformation model is a major departure form normal geodetic datums. From a geodetic perspective use of a semi-dynamic datum is relatively easy to implement and manage. For low accuracy users (at the metre level), the datum appears static and the deformation model can be ignored, facilitating its ease of use. For LINZ geodetic applications processes have been developed to enable use of the deformation model and conversions of NZGD2000 coordinates between the previous datum (NZGD49) and other reference systems. Users of the datum have readily accepted the concept of a semi-dynamic datum and to its implementation.

The deformation model was developed to support the accuracy requirements of the geodetic system. In fulfilling this requirement, it also provided a useful tool for other users to enable their surveys to accommodate the effects of

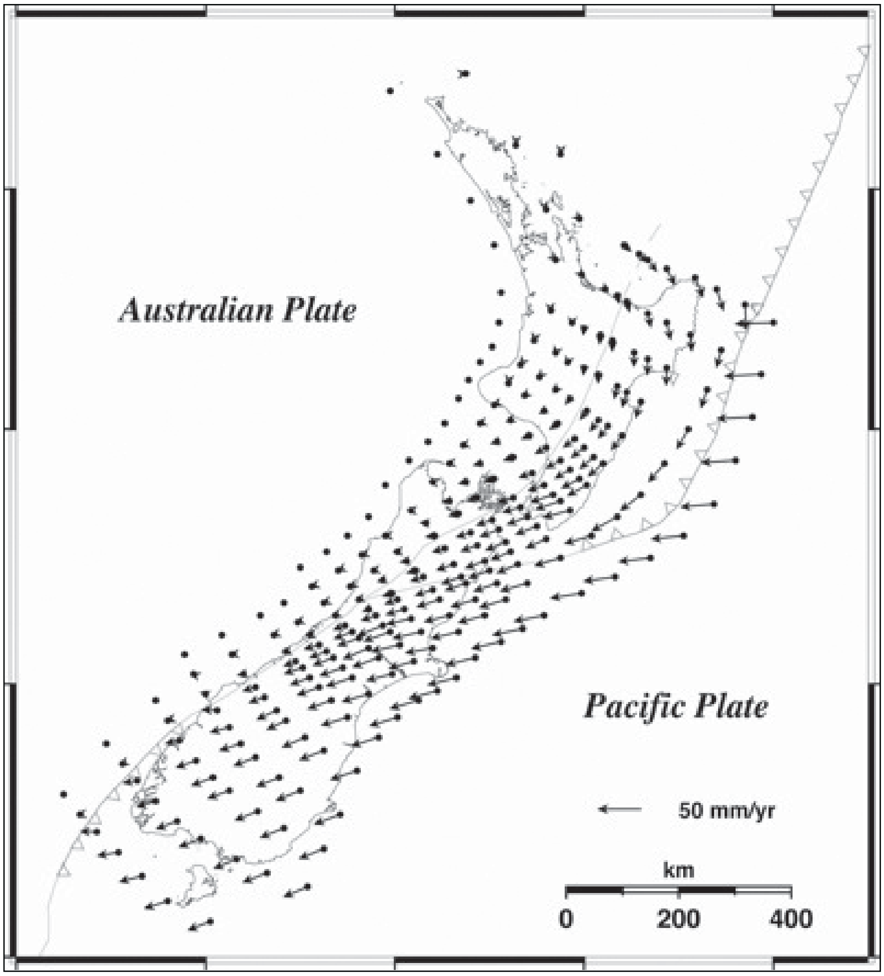

Fig. 1 NZGD2000 deformation model, with horizontal velocities relative to the Australian plate.

crustal deformation and thus maintain their consistency. For geodetic users, accounting for deformation is relatively straight-forward, however for non-geodetic users it can be complex and present an annoyance which is why non-geodetic users to date have not used the deformation model. Although using rather sparse data in some areas, the development of the deformation model and its implementation has gone well.

One of the fundamental aims of NZGD2000 was to maintain a relative accuracy of 5cm across New Zealand. With deformation due to plate tectonics amounting to movements of that magnitude/year, adoption of a static datum would have meant that the relative accuracy tolerance would have been exceeded after only one year. Incorporation of the deformation model has meant that after 10 years the relative accuracy tolerance is, in general, still being met but only by the geodetic users who apply the deformation model – not by the users with lower accuracy requirements who generally avoid using it.

Issues with the implementation of NZGD2000

As with implementing any new system, a number of limitations have been recognised and have, or are in the process of, being addressed.

Managing the deformation model

The surveys used to determine the initial deformation model in NZGD2000 are now over 15 years old. As time passes, errors in the determination of the velocities used in the deformation model have led to increasing errors in the calculated coordinates of marks in terms of the reference epoch, 2000.0. Research has indicated that in parts of New Zealand the existing deformation model is already unable to predict the current positions of geodetic marks at their required accuracy level. In effect, the datum is still steadily degrading with time, but at a much slower rate than if no deformation model had been used.

In addition, since NZGD2000 was implemented, New Zealand has been struck by several significant earthquakes such as the 15 July 2009 Fiordland earthquake (Subsequently, an earthquake in Canterbury on 4 September 2010 also caused significant deformation – the effects of which are still being analysed.) (Fig. 3). It is proposed that a patch will be added to the deformation model so that the effects of earthquakes can be accommodated.

Managing changing coordinates – CORS real time network

The issues with a semi-dynamic datum and the LINZ CORS network revolve around the management of coordinates at different epochs. In terms of coordinates, only NZGD2000 epoch 2000.0 coordinates are made readily available. However, a coordinate at epoch 2000.0 may not always satisfy the user's needs.

Providing 'current' or non-2000.0 coordinates of the CORS sites is not necessarily a trivial exercise. Three options are being evaluated:

- Publish a weekly position based on GNSS observations at each CORS station.
- Predict positions from a model fitted to the CORS time series, with the model allowing for some or all of: straight line; seasonal (annual, semi-annual) terms; steps (coseismic and/or equipment changes); aseismic tectonic deformation events.
- Predict positions from the NZGD2000 coordinates of the site and the NZGD2000 deformation model.

Option 1 has the clear advantage of providing the best 'current' coordinate. Option 2 enables coordinates to be generated at any epoch; however, the model is complex. Option 3 also enables positions to be generated at any epoch, but uses the existing deformation model which is much simpler.

Managing changing coordinates – surveys with long base lines

The New Zealand cadastral system is based on a fundamental legal premise common to most cadastral systems around the world that undisturbed survey marks form the primary evidence for property boundary definition. Accordingly, the New Zealand cadastral system is founded on a large number of physical survey marks and survey observations.

When using theodolite and electronic distance measuring equipment, connections to geodetic control marks are generally within 1-2 km of the survey area. For most practical purposes the effect of crustal deformation over these relatively short distances can almost always be ignored. More recently however, greater use is being made of GNSS systems and ties to geodetic control marks can include much longer lines, including lines to CORS stations in excess of 100km. With the greater survey accuracy achievable using such technology over long lines, the effects of crustal deformation must now be considered

To overcome these issues, all observations (or coordinates) need to be transformed into a common epoch; either epoch 2000.0 or the epoch of the survey. For these users the management of the dynamics can become a complex issue and annoyance. Ways of simplifying this process need to be sought.

Managing the Spatial Alignment of the Cadastral System

One of the key drivers for the move to NZGD2000 was the automation of New Zealand's survey and titles systems. All cadastral boundaries in New Zealand now have geodetic coordinates – although some are more accurate than others. This "geodetic cadastre" is managed in a system called Landonline.

While applying the deformation model and updating geodetic data is a relatively trivial task using tools developed to undertake these tasks, updating the cadastral data and boundary marks connected to this control is a more complex task due to the sheer volume of marks concerned.

Currently, when geodetic marks have their coordinates updated, there is no efficient process to update the nearby cadastral coordinates by least squares adjustment. Consequently, LINZ is actively looking at efficient methods of updating large numbers of cadastral coordinates, so that the cadastre can maintain its accuracy after a significant geodetic update.

Misalignment of readjusted historic geodetic control with new surveyed geodetic control

The development of NZGD2000 necessitated the upgrading of geodetic control to NZGD2000 status. This was achieved in two ways:

- Survey using GNSS of existing and new control; and
- Readjustment of existing control using historical observations

It has become clear that there can be a misalignment between the surveyed and readjusted control such that if a cadastral surveyor uses a mixture of both control types they can fail to meet their cadastral survey accuracy requirements. The solution to the problem has been to downgrade the accuracy of doubtful readjusted geodetic control so that its stated accuracy more accurately reflects its true accuracy. This is necessitating the provision of a larger amount of newly surveyed control than was originally envisaged.

Future developments of NZGD2000

NZGD2000 is now 12 years old however continued development of it continues to ensure that its spatial accuracy meets user requirements. A number of developments are underway and potential future developments are being considered.

Updating the deformation model

Research has indicated that in parts of New Zealand, the existing deformation model is already unable to predict the current positions of geodetic marks at their required accuracy level. Work is currently underway to develop a new deformation model and this will be incorporated into the datum to ensure that its spatial accuracy can be maintained.

Vertical deformation model

The current velocity model assumes a zero vertical velocity model. Clearly vertical deformation does occur in New Zealand although at a generally lesser rate than horizontal deformation (except in the volcanic zones of New Zealand). There is a need to consider and include a vertical component in the deformation model so that the vertical accuracy of the datum can be maintained.

CORS real time – tools for managing coordinates

An automated post processing system (PositioNZ PP) is being developed for the LINZ CORS network. One of the advantages of such a system will be that it will generate official NZGD2000 coordinates for marks using the deformational model and tools to ensure that corrections are applied efficiently and correctly.

Tie to the ITRF - Going fully dynamic

NZGD2000 is realised in terms of ITRF96. Significant improvements have been made to the ITRF and for ease of computations and better data management, it is logical that NZGD2000 be moved to a later realisation of the ITRF. While the inclusion of a deformation model in NZGD2000 has meant that the accuracy of the datum has been able to be maintained for a much longer period than if it were a

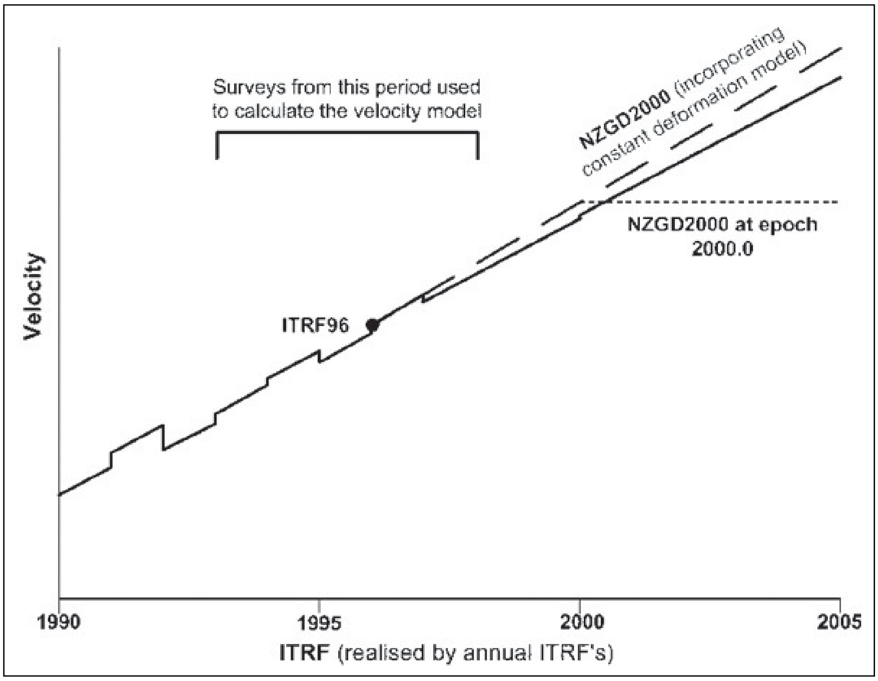

Fig. 2 Relationship between ITRF and NZGD2000.

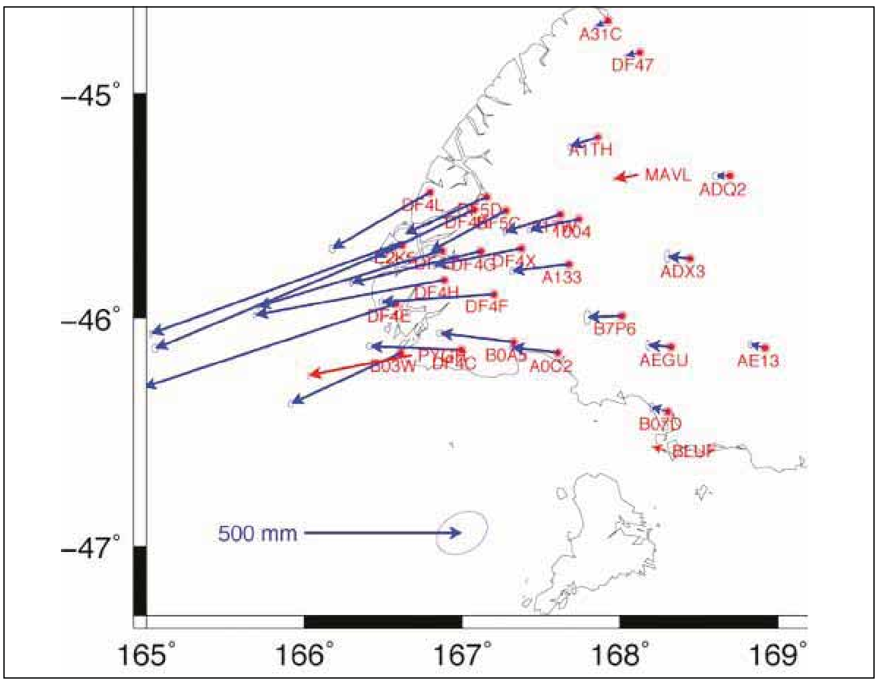

Fig 3. Observed horizontal displacements from the 2009 Fiordland earthquake (Winefield et al.2010).

static datum, it is apparent that an updated deformation model will be required shortly. In the relatively near future a new or updated datum will be required – NZGD201X. Given the acceptance of a semi dynamic datum in New Zealand, the tools developed to manage its dynamics, and the experience gained in managing coordinates in a dynamic environment, it is logical that consideration should be given to a fully dynamic datum that maintains a constant relationship with the ITRF at some time in the future.

Summary

NZGD2000 has now operated in New Zealand for over 10 years. The use of a semi dynamic datum has been well accepted and its implementation and use have been relatively straight forward from a technical and geodetic perspective. The use of the deformation model has meant that the accuracy of the datum has been maintained over a much longer time period than if it were a static datum. A number of issues have been identified from a user perspective, particularly that of maintaining the accuracy of the deformation model and also allowing users of the system to incorporate long distance observations in their surveys or to use real time CORS networks.

> The New Zealand cadastral system is based on a fundamental legal premise common to most cadastral systems around the world

Future enhancements to NZGD2000 will continue to ensure user requirements are met. The next step will be upgrading the deformation model, inclusion of a vertical component in the model, and perhaps moving to a later realisation of the ITRS. In the longer term, consideration will be given to moving to a fully dynamic datum but such a move is expected to be some years away.

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Geodesic based trajectories in navigation

The paper presents the current and uniform approaches to sailing calculations highlighting recent developments. We published the first part of the paper in May 11. Here we present the concluding part

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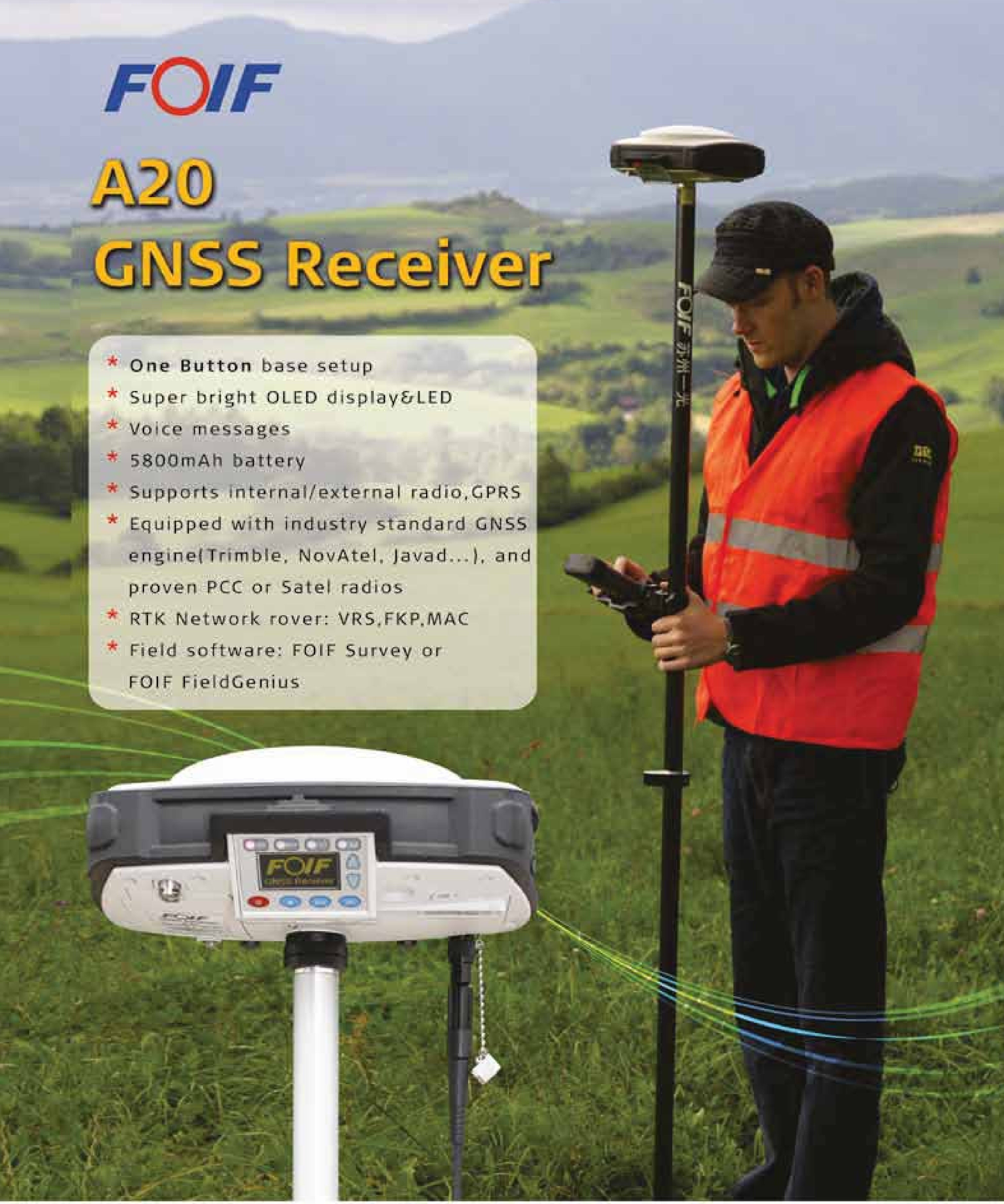
ECDIS approach

In the course of navigation programmes for ECDIS purposes it became apparent that the standard text books of navigation were perpetuating a flawed method of calculating rhumb lines on the Earth considered as an oblate spheroid. On further investigation it became apparent that these incorrect methods were being used in programming a number of calculator/computers and satellite navigation receivers. Although the discrepancies were not large, it was disquieting to compare the results of the same rhumb line calculations from a number of such devices and find variations of a few miles when the output was given, and therefore purported to be accurate, to a tenth of a mile in distance and/or a tenth of a minute of arc in position. This paper presents and recommends the guidelines that should be used for the accurate solutions. Most of these may be found in standard geodetic text books, such as, but also provided are new formulae and schemes of solution which are suitable for use with computers or tables. The paper also takes into account situations when a near-indeterminate solution may arise. The data for these problems do not refer to actual terrestrial situations but have been selected for illustrative purposes.

The references also present the review of different approaches to contact formulae for the computation of the position, the distance and the azimuth along a great ellipse. The proposed alternative formulae are to be primarily used for accurate sailing calculations on the ellipsoid in a GIS environment as in ECDIS and other ECS. Among the ECDIS requirements is the need for a continuous system with a level of accuracy consistent with the requirements of safe navigation. At present, this requirement is best fulfilled by the Global Positioning System (GPS). The GPS system is referenced to World Geodetic System 1984 Datum. Using the ellipsoid model instead of the spherical model attains more accurate calculation of sailing on the Earth. Therefore, we aim to construct a computational procedure for solving the length of the arc of a geodesic path, the waypoints and azimuths along it. We aspire to provide the straightforward formulae involving the great elliptic sailing based on two scenarios. The first is that the departure point and the destination point are known. The second is that the departure point and the initial azimuth are given (direct and inverse geodetic problems on reference ellipsoids).

As a minimum, an ECDIS system must be able to perform the following calculations and conversions [Weintrit, 2009]:

- geographical coordinates to display coordinates and display coordinates to geographical coordinates;
- transformation from local datum to WGS-84;
- true distance and azimuth between two geographical positions;
- geographic position from a known position given distance and azimuth (course);
- projection calculations such as great circle and rhumb line courses and distances;
- "RL-GC" difference between the rhumb line and great circle in sailing along the great circle (or great ellipse?).


FOIF
A20
GNSS Receiver
* One Button base setup
* Super bright OLED display&LED
* Voice messages
* 5800mAh battery
* Supports internal/external radio,GPRS
* Equipped with industry standard GNSS engine(Trimble, NovAtel, Javad...), and proven PCC or Satel radios
* RTK Network rover: VRS,FKP,MAC
* Field software: FOIF Survey or FOIF FieldGenius
FOIF

The ECDIS allows the navigator to create waypoints and routes including setting limits of approach and other cautionary limits. Both rhumb line and great circle routes can be defined. Routes can be freely exchanged between the ECDIS and GPS or ARPA. Route checking facility allows the intended route to be automatically checked for safety against limits of depth and distance as defined by the navigator.

The mariner can calculate and display both a rhumb line and a great circle line and verify that no visible distortion exists between these lines and the chart data. Authors predict the early end of the era of the rhumb line. This line in the natural way will go out of use. Nobody after all will be putting the navigational triangle to the screen of the ECDIS. Our planned route need not be a straight line on the screen. So, why hold this line still in the use? Each ship's position plotted on the chart can be the starting point of new updated great circle, or saying more closely, great ellipse or geodesic trajectory.

It is an important question whether in the ECDIS time Mercator projection is still essential for marine navigation. Do we really need it? And what about loxodrome? Let start navigation based on geodesics. It is high time to forget the rhumb line navigation and great circle navigation, too. But first we need clear established methods, algorithms and formulae for sailing calculations. But it is already indicating the real revolution in navigation - total revolution. We will be forced to make the revision of such fundamental notions as the course, the heading and the bearing.

And another very important question: do you really know what kind of algorithms and formulae are used in your GPS receiver and your ECS/ECDIS systems for calculations mentioned above? We are almost sure your answer is negative. So, we have got a problem – a serious problem.

Review of recently published papers

We surveyed last reports and research results in the field of navigational calculations' methods applied in marine navigation that deserve to be collected together in [Weintrit, Kopacz, 2011]. Some of these results have often been rediscovered as lemmas to other results. Since 1950 till 2010 many professional magazines and journals published some papers on the great ellipse and on the spheroidal Earth. The following particular problems were discussed among the others: practical rhumb line calculations on the spheroid [Bennet, 1996], geodesic inverse problem, direct and inverse solutions for the great elliptic and line on the reference ellipsoid, loxodromic navigation [Carlton-Wippern, 1992], formulas for the solution of direct and inverse problems on reference ellipsoids using pocket calculators, geometry of loxodrome on the ellipsoid, geometry of geodesics, geodesic line on the surface of a spheroid [Bourbon, 1990], great circle equation, novel approach to great circle sailing [Chen, Hsu & Chang, 2004], vector function of traveling distance for great circle navigation, great circle navigation with vectorial methods [Nastro & Tancredi, 2010], vector solution for great circle navigation [Earle, 2005], vector solution for navigation on a great ellipse [Earle, 2000], navigation on a great ellipse, great ellipse solution for distances and headings to steer between waypoints [Walwyn, 1999], great ellipse on the surface of the spheroid [Williams, 1996], vector solutions for azimuth [Earle, 2008], sphere to spheroid comparisons [Earle, 2006], great circle versus rhumb line cross-track distance at mid-longitude [Hickley, 1987], modification of sailing calculations, practical sailing formulas for rhumb line tracks on an oblate Earth, distance between two widely separated points on the surface of the Earth, traveling on the curve Earth, new meridian arc formulas for sailing calculations in GIS [Pallikaris, Tsoulos & Paradissis, 2009], new calculations algorithms for GIS navigational systmes and receivers, improved algorithms for sailing calculations [Pallikaris, Tsoulos & Paradissis, 2010], new algorithm for great elliptic sailing (GES) [Pallikaris & Latsas, 2009], shortest paths, sailing in ever-decreasing circles [Prince & Williams, 1995], long geodesics on the ellipsoid, spheroidal sailing and the middle latitude [Sadler, 1956], general non-iterative solution of the inverse and direct geodetic problems, comparison of spherical and ellipsoidal measures [Tobler, 1964], navigating on the spheroid [Tyrrell, 1955; Williams, 2002], direct and inverse solutions of geodesics on the ellipsoid with application of nested equations, loxodromic distances on the terrestrial spheroid [Williams, 1950], Mercator's rhumb lines: a multivariable application of arc length, navigating along geodesic paths on the surface of a spheroid [Williams & Phythian, 1989], shortest distance between two nearly antipodean points on the surface of a spheroid, shortest spheroidal distance [Zukas, 1994], navigating on a spheroid.

Conclusions

This article is written with a variety of readers in mind, ranging from practising navigators to theoretical analysts. It was also our goal to present the current and uniform approaches to sailing calculations highlighting recent developments. Much insight may be gained by considering the examples that have recently proliferated in the literature reviewed above. We present our approach to the subject and place special emphasis on the geometrical base from a general point of view. Of particular interest are geodesic lines, in particular great ellipse calculations. The geometry of modelling structures implies the calculus essentially, in particular the mathematical formulae in the algorithms applied in the navigational electronic device and systems. Thus, is the spherical or spheroidal model the best fit in the local approximations of the Earth surface? We show that generally in navigation the essential calculating procedure refers to the distance and angle measurement what may be transferred to more general geometrical structures, for instance metric spaces, Riemannian manifolds. The authors point out that the locally modelling structure has a different "shape" and thus the different curvature and the flow of geodesics. That affects the calculus provided on it. The algorithm applied for navigational purposes, in particular ECDIS should inform the user on actually used mathematical model and its limitations. The question we also ask affects the range and point in applying the loxodrome sailing in case the ECDIS equipped with the great circle (great ellipse) approximation algorithms of given accuracy replaces the traditional nautical charts based on Mercator projection. The shortest distance (geodesics) depends on the type of metric we use on the considered surface in general navigation. The geodesics can look different even on the same plane if different metrics are taken into consideration. Let us observe for instance the diameter of the parallel of latitude on a conical circle which does not pass its centre. That differs from both the plane and spherical case. Our intuition insists on the way of thinking to look at the diameter as a part of geodesic of the researched surface crossing the centre of a circle. However the diameter depends on the applied metric, thus the shape of the circles researched in the metric spaces depends on the position of the centre and the radius. It is also important to know how the distance between two points on considered structure is determined, where the centre of the circle is positioned and how the diameter passes. Changing the metric causes the differences in the obtained distances. For example π as a number is constant and has the same value in each geometry it is used in calculations. However π as a ratio of the circumference to its diameter can achieve different values, in particular π [Kopacz, 2010]. The navigation based on geodesic lines and connected software of the ship's devices (electronic chart, positioning and steering systems) gives a strong argument to research and use geodesic-based methods for calculations instead of the loxodromic trajectories in general. The theory is developing as well what may be found in the books on geometry and topology. This motivates us to discuss the subject and research the components of the algorithm of calculations for navigational purposes.

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Russia upholds ban on high resolution data

A Moscow court upheld a ban on prohibiting ScanEx, a Russian research and development company, from distributing satellite images of Earth at a resolution higher than two meters. Scanex works under license from the Russian federal space agency, Roscosmos, to collect, process and disseminate Earth remote sensing data. A 2008 ban prohibited ScanEx from distributing high-resolution images, considered by the defence ministry to contain sensitive military information. ScanEx appealed the ban, citing the Russian defence minister as saying in 2006 that all restrictions on satellite imagery resolution would be lifted. Now the company would file another appeal. *en.rian.ru*

China gets public support to crackdown illegal mapping

With the help of approximately 15,000 citizens, China's State Bureau of Surveying and Mapping conducted more than 2,200 law-enforcement operations involved in a nationwide crackdown on illegal surveying and mapping last year, announced SBSM. During this process, it listed ten major cases of illegal surveying and mapping. One case involved a Japanese national who was using a GPS receiver to collect information on 598 geographic coordinates in the name of sightseeing and conducting environmental inspection. Of these coordinates, 588 were within Xinjiang, including 85 within the Tacheng Military Zone. *www. english.cri.cn*

South Korea raids Google offices

South Korean police raided Google's Seoul office on suspicion that the company collected user location data without consent, adding to global pressure on the mobile industry to address privacy concerns. The investigation focuses on Google's mobile advertising service AdMob, which the company purchased last year for USD 750 million. Google has consistently maintained that Android only collects location data with user consent and that the data is anonymised when sent to the company, but a visceral public reaction to recent reports on smartphone's location awareness have shown that people are intensely uncomfortable with being "tracked.". *www.mobiledia.com*

Pakistan should ban Google maps

Defence and diplomatic analysts demanded that Government of Pakistan should direct Google to stop taking satellite images of sensitive locations throughout the country or ban it. Recently, Google has updated satellite imagery of the entire Mehran Naval Base, assets, compounds, buildings, its surroundings fields and Chakora Nala around the base walls. By going through the entire base via Google maps and navigating through the images available there, one can not deny the fact that this service might have served terrorists for laying out their attack plan. *www.nation.com.pk*

Survey of India to unveil new road maps

The Survey of India (SoI) will be bringing out two different sets of road maps, Open Series Maps and Defence Series Maps. The printing of the maps is scheduled to begin in June and each of the 5,000 individual topographical maps will show details of every area, its expansion and development. Every individual map will pertain to an area covering 720 sq km, and adheres to a plan using latitudes and longitudes. The latest WGS-84 (World Geodetic System), the current standard for use in the field of cartography, geodesy and navigation were also adopted, adding to the accuracy of co-ordinates shown in the GPS. Once ready, these individual maps could be put together for a map of the country, and of specific cities, districts, and states. A new and revised map of the country is necessary for practically all purposes of developmental planning and creating more infrastructures. *www.timesofindia.com*

Google's StreetView all set to image India

Google Inc. launched a fleet of cars to capture street images to create its online mapping in India. However, the Internet giant is under fire from several overseas governments for invading privacy through StreetView. The drivers of the StreetView vehicles will photograph streets in the southern Indian city of Bangalore and that the service will eventually cover the rest of the country. It didn't give any specific timeframe on when the images will be available on StreetView. *www.online.wsj.com*

Melbourne to launch online mapping system

The City of Melbourne invited several small focus groups to test a new municipal mapping system. It is currently in development phase. It is designed to display community points of interest like parks and healthcare centres, for example, and has been in the works for the last 18 months according to the council. It has been built for use by a diverse community, including ratepayers, residents, citizens, seniors, young people, small and large business people, tourists, heritage groups etc. *www. zdnet.com.au*

Vietnam to launch online mapping service

The Vietnam Mapping and Measurement Bureau will put Vietnamese maps to the Internet later this year. The bureau completed the first stage of the project. A website of Vietnamese maps is under construction. Online maps of Vietnam will show in details the borders between Vietnam – China, Vietnam – Laos, Vietnam – Cambodia and two archipelagos Hoang Sa (Parcel) and Truong Sa (Spratly) as Vietnam's territory. Only online maps that are provided by competent agencies of Vietnam are legal maps. For wrong information about Vietnam's sovereignty on online maps supplied by Google Map and National Geographic, the Vietnam Mapping and Measurement Bureau has added explanations and instructions for users of online maps of Google and National Geographic. *www. english.vietnamnet.vn*

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India's GSAT-8 satellite to help GAGAN

India's advanced communication satellite GSAT-8 was successfully launched recently into its geosynchronous transfer orbit. Weighing about 3100 Kg, GSAT-8 is configured to carry 24 high-power transponders and a two channel GPS-aided GEO Augmented Navigation (GAGAN) payload. Once it was introduced into its intended orbit, ISRO's master control facility in Karnataka's Hassan took control of the satellite and placed it into the geostationary orbit. The Ku-band (11-14 Gigahertz) transponders of the satellite will augment the capacity of the INSAT system. While, GAGAN will improve the accuracy of positioning information received from GPS satellite through improved ground-based network. *www.timesofindia.com*

India to share 26/11 GPS details

India will share with the Pakistani Judicial Commission details of the GPS used by the terrorists involved in the 26/11 Mumbai terror attacks so as to enable it to match the device with the GPS packing carton found by Pakistani authorities at a house in Karachi. Sources said by matching the GPS device used by the 26/11 attackers to navigate in Indian waters on fishing trawler Kuber with the packing carton, Islamabad would be able to clearly establish the role of Pakistani terrorists and the ISI in executing the Mumbai attacks of 2008. *www.indianexpress.com*

Russia opens negligence case over loss of Glonass satellites

Russian prosecutors have opened a criminal case on charges of negligence that led to the loss of three Glonass satellites last year. The satellites, meant to conclude the formation of Russia's Glonass navigation system, were lost when a Proton-M carrier rocket veered off course and crashed in the Pacific Ocean in December. "Criminal proceedings have been launched against space officials who were responsible for the loss of the satellites," the prosecutors said. *en.rian.ru*

GPS modernization on agenda for PNT advisory board meeting

The National Space-Based Positioning, Navigation, and Timing (PNT) advisory board would meet soon to discuss GPS modernization, interoperability with other GNSS systems, and future challenges to PNT service providers and users, such as protecting the emerging role of PNT in cyber networks, including the need for backups, among other agenda points. The National Space-Based PNT Advisory Board is a federal advisory committee comprised of experts from outside the U.S. government that provides counsel to the National Space-Based PNT Executive Committee and other government agencies regarding the nation's space-based PNT policy, planning, program management, and funding profiles in relation to the current state of national and international space-based PNT services.

QUALCOMM announces support for Russian GLONASS

QUALCOMM has announced product support for the Russian GLONASS satellite system and the unique capability to utilize both the GPS and GLONASS networks simultaneously for greater location performance. The supplementary signals from this extended satellite network provide more accurate location information for the growing number of location based applications and services. *www.usamarketnews.com*

Troubled GPS Satellite SVN49 Removed from Active Service

According to a recently issued NANU, the GPS satellite carrying the problematic L5 test transmitter, SVN49/PRN01, has been decommissioned from active service. Although it was never set healthy for general use, it was being tracked by stations of the International GNSS Service and data was made available to engineers and scientists for test purposes. According to data from the IGS station TAH1 on the island of Tahiti, the L1/L2 signals were switched off at about 14:38 GPS time. *www.navcen.uscg.gov*

ISRO Himalayan glaciers retreating

A comprehensive study of ISRO satellite images revealed 75 percent of Himalayan glaciers are on the retreat, with the average shrinkage being 3.75km during the 15 years under study. The grim findings come after raging controversy over claims in the 2007 IPCC report of Himalayan glaciers disappearing by 2035, which were later retracted. The project, which studied 2,190 glaciers, was commissioned by the Ministry of Environment and Forests and Department of Space, Government of India, to break myths about the disappearance of Himalayan glaciers. However, the findings are sure to raise concern over the health of Asia's 'water towers'. The study used satellite images taken by Resourcesat-1 over a period of 15 years (1989-2004). *www.economictimes.indiatimes.com*

Venezuela to use Chinese technology

Venezuela has signed manufacturing contract with China for the development of its remote sensing (RS) satellite to be launched in October 2012. This RS satellite will be used for monitoring of natural phenomena, such as earthquakes, floods and heavy rains. The life of satellite will be five to six years. *www.english.peopledaily.com*

Singapore's first satellite sends images

The first Singapore-made micro-satellite, X-Sat, started sending live images. The satellite was launched by India's PSLV-C16 rocket. The images - which were captured at a height of 800km - can help scientists monitor soil erosion and environmental changes. *www.asiaone.com*

ISRO to expand research facilities

ISRO is enhancing its capabilities by setting up more than half a dozen critical facilities across its installations. They include a national database for emergency management and a multi-mission earth observation centre for satellites which will be set up at Hyderabad, besides an advanced research and development centre for spacecrafts to come up on 530 acres in the Science City at Chitradurga. There are few more such initiatives being undertaken. *www.hinduonnet.com*

Iran to launch two satellites soon

Iran will soon launch two satellites into space to take high resolution wall maps and aerial photos of locations around the globe. Iran will send Fajr (Dawn) satellite into space by September, while the Tolou (Sunrise) satellite will be launched in February 2012. The national Fajr satellite was developed and produced by Iranian aerospace experts in less than a year. Tolou would have a lifespan of one and a half years and would capture images with a resolution of 50 meters and then transmit them to stations on earth. *www.xinhuanet.com*

UAE, Thailand sign MOU cooperation

The Emirates Institution for Advanced Science & Technology (EIAST) signed a memorandum of understanding (MOU) with Thailand's Geo-Informatics and Space Technology Development Agency (GISTDA) to further strengthen cooperation in the fields of space technology and application. The two organisations will work together on various areas including remote sensing, space sciences, satellite communications, satellite navigation, satellite technology development and application and ground infrastructure development and its utilisation. *www.wam.ae*

Satellite to predict earthquakes

As part of the proposed earthquake monitoring network, China will launch China Seismo-Electromagnetic Satellite (CSES) in 2014. It aims to detect electromagnetic anomalies in the atmosphere. The satellite has been in development since 2003 and is the first spaced-based component of the network. Its data will be correlated with data from ground-based monitoring systems. The network is eventually intended to provide advance warning of earthquakes, such as the one off the coast of Japan very recently. *www.scidev.net*

Galileo update

Galileo prepares for October launch

The European Space Agency (ESA), Arianespace and the European Commission announced that the first two satellites of Europe's global navigation satellite system, Galileo, will be launched on October 20, 2011. This will be the first of a series of Galileo satellite launches by Arianespace from Europe's Spaceport in French Guiana.

The announcement follows a detailed review held on May 12, under the chairmanship of the Director General of the ESA and with the participation of Arianespace and industrial prime contractors, which concluded that the space and ground elements will be ready for a launch in October.

The two Galileo satellites will be deployed using a Soyuz launcher. The October launch will mark the inaugural Soyuz flight from its new launch facilities in French Guiana, built in the framework of a programme of the ESA. Jean-Jacques Dordain, Director General of ESA, said, "With this launch, we will also be opening a new chapter in our own history, as we start Soyuz operations from the Guiana Space Centre. More than ever, we will be able to deliver the full range of launch services expected by our esa.int

EU lowers price tag for Galileo satellite project

The European Union set the date for the launch of the first satellites in its Galileo global navigation system and said the long-delayed programme would come in below budget. "This launch is of historical importance," Antonio Tajani said of a plan that will eventually put 30 satellites into orbit and provide global positioning data for cars, ships, aircraft, railroads and mobile phone users, among others.

"We are cutting the costs as compared to the estimates," Tajani said, saying the forecast figure of 3.4 billion euros ($4.76 billion) would be lowered once the price of the last two contracts is finalised at Le Bourget in Paris on June 22. The programme, which must be fully funded by the EU, has long run over budget, with the European Commission saying in January it needed 1.9 billion euros more to complete the programme. That request has now been dropped. *www.reuters.com*

ESA innovation prize for Sat Nav ideas with market potential

In sponsoring the ESA Innovation Prize in line with the European Satellite Navigation

Competition (ESNC), the European Space Agency (ESA) is looking for business ideas that

promote the commercial use of satellite navigation. In addition to a EUR 10,000 cash

prize, the winner may get the chance to implement the idea at an ESA Business

Incubation Centre (ESA BIC). *www.galileo-masters.eu*

SatNav in JV with AND

SatNav Technologies has announced plans to set up a Joint Venture based on shared vision and complementary business opportunities. From an India perspective, the deal will give SatNav access to the best mapping technologies in the world and upgrade their Indian map IP in line with the standards followed worldwide. It will also give SatNav access to global markets and large clients that are already serviced by AND. SatNav's map data of India is exhaustive, covering over 1000 cities and millions of point of interest apart from a comprehensive highway network. *www.satguide.in*

Microsoft's Skype acquisition

Microsoft agreed to buy Internet phone company Skype Technologies SA for $8.5 billion in cash. The deal is subject to regulatory approval. Microsoft plans to integrate Skype's functions to its Xbox and Kinect game consoles, outlook email program, and Windows smart phones but will continue to support it on other software platforms.

Nokia, CNN collaborate on mapping

CNN and Nokia announced a multi-level international collaboration where Nokia becomes a key part of CNN's roster of mapping providers. The collaboration harnesses the companies' strengths in global newsgathering, user-generated content, mapping technologies and location-based services. The collaboration debuted with the use of Nokia's 3D Maps across CNN's platforms in its recent coverage of the British royal wedding. *www.cnn.com*

CSR offers traffic solutions for India

CSR has announced that "Where is My Bus" and "Geo Traffic" solutions are two such solutions for the commuters to find out the fastest as well as the shortest route to any destination and to get the real-time mapping results of the traffic speed in various parts of the New Delhi city. CSR's "learning server" studies the pattern of traffic in areas where the tracked vehicles are moving and interprets and predicts the composite traffic speed in that area. Taking the GPS feed and the data that is collected, for the passengers, the CSR solution is capable of providing a time estimation of when a certain vehicle will arrive at a certain stop. *www.brand-comm.com*

E-cigarettes to fuel LBS business

Blu has developed packs of e-cigarettes with sensors that will let users know when other e-smokers are nearby. The packs vibrate when a smoker nears a retail outlet that sells Blu cigarettes. One can consider it as the introduction of location-based service exclusively for smokers. The new "smart packs," which will go on sale next month for USD 80 for five e-cigarettes, are equipped with devices that emit and search for the radio signals of other packs. *www.nytimes.com*

All eyes on USD 2.5 billion LBS market

Google and Apple are using users' data to build maps of the world, maps that help smartphones quickly pinpoint their locations. They are using the signals from cell towers and Wi-Fi hotspots, as navigational beacons is particularly useful in places where GPS satellite signals are weak, like urban areas or anywhere indoors. Mobile advertising which includes LBS could be a USD 2.5 billion market by 2015, according to Frost & Sullivan, and ads tied to a location are much more lucrative than other ads.

LBS on Aircel without a GPS handset

Aircel plans to offer its 2G and 3G subscribers better location based services and to get real time tracking, navigation information and information services while on the move, without the need to buy a GPS enabled phone from next month. Aircel, has selected Ericsson to provide the mobile positioning systems for its subscribers. These services subscribers will be able to find nearby restaurants or gyms, the fastest route home, or keep track of children or the elderly with a tracking service.

CHC's GPS mapping solutions

CHC has launched Nava GPS handheld series designed for any meter-level GPS mapping applications such as in forestry, agriculture, utilities, and local government, which are mainly capturing data about assets. It is easy-to-use and provide the necessary features for data collection and mapping including point, line and area data capture, import and export to MIF and SHP format. *www.chcnav.com*

JAVAD calls on to protect GPS

Javad Ashjaee, president and CEO of JAVAD GNSS, has called upon the U.S. government to protect GPS as a national asset, invoking the many billions of dollars invested in it, and likening the LightSquared initiative for high-powered terrestrial transmitters to "aggression." The statement came in response to a written communication to Ashjaee, describing recent preliminary tests of some high-precision receivers under LightSquared conditions by NASA's Jet Propulsion Laboratory.

RTK Receiver smaller than Credit Card

Septentrio has announced the AsteRx-m, a very low power GPS/GLONASS dual-frequency RTK receiver which is smaller than a credit card. The new board is aimed specifically at integration in hand-held devices, mobile computing platforms and other solutions requiring high accuracy combined with low power in applications where space is at a premium. It offers full dual-frequency GPS-only RTK capability while consuming less than 500 mW and GPS/GLONASS RTK at less than 600 mW.

Septentrio announces Multi-GNSS Reference Station Receiver PolaRx4

Septentrio PolaRx4 is a versatile multi-frequency high-performance GNSS receiver providing network operators and scientific users with high-quality tracking and measurement of all available and upcoming GNSS signals. It is designed to serve as a future-proof base station, with innovative GNSS signal processing, extensive networking capabilities, robust design and an intuitive user interface.

NavCom announces dealer in Turkey

NavCom Technology, Inc. has formed a strategic partnership with Anka Geographic Information Technologies Industry Trade Ltd. Co. (Ankageo). It will bring NavCom's GNSS product and positioning solutions, including the recently released SF-3040, StarFire™/RTK GNSS Pole-mount Receiver, to the Turkish market. *www.navcomtech.com.*

SmartNet Germany

Leica Geosystems Germany started its own GNSS Network RTK service on April 1st. SmartNet Germany is based on a close partnership between SAPOS, the service of Surveying Authorities of the Federal Republic of Germany and Leica Geosystems GmbH Vertrieb. The new GNSS Network service uses high quality data and coordinates provided by SAPOS® reference stations itself. *www.leica-geosystems.de*

Leica SmartWorx Viva 3.5

Version 3.50 of Leica SmartWorx Viva onboard software is now available. It supports both Leica Viva GNSS and Viva TPS instruments and also controls the newly released Leica Viva TS12 Total Station. It includes new features like Leica Active Assist, Sketching templates, DTM import, new unlevelled Setup app support, etc. *www.leica-geosystems.com*

GeoTranslate 5.1 Upgrade

Blue Marble Geographics has announces the upgrade of their developer tool GeoTranslate. It is available within GeoCore, Blue Marble's all in one geospatial developer tool kit. It is the latest vector translation and feature manipulation tool from Blue Marble Geographics.

Viva TS12 Performance Robotic Package

Leica Geosystems Viva TS12 Performance Robotic Package is a cost-effective system which provides everything needed for efficient daily surveying in one powerful package comprising the Leica Viva TS12 Total Station, the Leica Viva CS10 Controller and the easy-to-use Leica SmartWorx Viva Onboard Software. *www.leica-geosystems.com*

Maptek operations in India

Maptek has established an office in New Delhi to service the Indian mining market. Its products can help meet the demand by miners for better technical capability. Experienced Indian staffs have undertaken intensive training in Australia to become familiar with Maptek products and service delivery standards. *www.maptek.com*

Esri and DOI Introduce Landsat Data for the World

Working in close collaboration with the US Department of the Interior (DOI), Esri has released Landsat image services. These provide access to almost four decades' worth of Global Land Survey (GLS) Landsat data developed by the National Aeronautics and Space Administration (NASA) and DOI's US Geological Survey. Esri provides access to the full multispectral, multitemporal Landsat data for free on ArcGIS Online as dynamic image services. Esri has also published an interactive website that leverages these Landsat image services to provide a starting point for understanding earth changes over time.

Ashtech MobileMapper 10

Spectra Precision introduced Ashtech MobileMapper 10, which is a lightweight, low power and cost-effective mapping solution with real-time meter level accuracy. It can improve the quality of the GIS data, improve productivity and reduce operating costs. *www.ashtech.com*

Trimble on acquisition spree

Trimble has made two major acquisitions - Dynamic Survey Solutions and MyTopo. The acquisition of Dynamic Survey is expected to expand Trimble's presence in the seismic survey industry. MyTopo brings top-notch maps with enhanced quality and rich features to its customers and partners such as Cabela's and Backpacker magazine."*www.trimbleoutdoors.com.*

New LX-2 L-Band OEM Board

Hemisphere GPS has introduced the LX-2, a new second generation L-Band differential GPS OEM receiver board. The new LX-2 augments Hemisphere GPS' Crescent P100 and Eclipse P200 GPS receivers with OmniSTAR differential HP, XP or VBS signal support. This reliable and globally available differential GPS option is one of several differential solutions offered by Hemisphere GPS. *www.hemispheregps.com.*

MARK YOUR CALENDAR

June 2011

2011 Cambridge Conference
26 June - 1 July
Winchester, England UK
www.cambridgeconference.com

ICL-GNSS 2011: Localization and GNSS Conference
29-30 June
Tampere, Finland
www.icl-gnss.org

July 2011

Summer School "Advanced Spatial Data Infrastructures
4 – 8 July (Advanced SDI-Management)
7-15 July (Advanced SDI-Professional)
Leuven, Belgium
www.spatialist.be

Survey Summit
7 - 11 July
San Diego, California
www.thesurveysummit.com

ESRI International User Conference
11-15 July
San Diego, USA
www.esri.com

2011 Esri Education User Conference
9 - 12 July
San Diego, California, US
www.esri.com/educ

ESA International Summer School on Navigation Satellite Systems 2011
20-30 July
Berchtesgaden, Germany
www.munich-satellite-navigation-summerschool.org

August 2011

XXV Brazilian Cartographic Congress
21-24 August
Curitiba - State of Paraná, Brazilia
sbc.tatiana@gmail.com

7th International Symposium on Digital Earth
23-25, August
Perth, Australia
www.isde7.net

HealthGIS
4-6 August
New Delhi, India
http://e-geoinfo.net/healthgis2011

Scientific and Fundamental Aspects of the Galileo Program
31 August – 2 September
Copenhagen, Denmark
www.congrex.nl

September 2011

ICG-6: Sixth Meeting of the International Committee on GNSS
5-9 September
Tokyo, Japan
www.unoosa.org

Middle East Geospatial Summit
13 - 15 September
Doha, Qatar
barbora.kuckova@flemingeurope.com

ION GNSS 2011
20-23 September
Portland, USA
www.ion.org

INTERGEO
27 - 29 September
Nuremberg, Germany
www.intergeo.de

October 2011

ACRS 2011
3-7 October
Taipei, Taiwan
www.acrs2011.org.tw

AfricaGIS 2011
10-14 October
Cairo, Egypt
www.eis-africa.org/EIS-Africa

November 2011

IMTA Global Conference & Trade Show
10-11 November
Bangkok, Thailand
www.imtamaps.org

2011 Precise Time and Time Interval Systems and Applications Meeting
14-17 November
Long Beach, California USA
www.pttimeeting.org

Regional Geographic Conference – UGI 2011
14-18 November
Santiago, Chile
www.ugi2011.cl

International Symposium on GPS & GNSS
15-17 November
Sydney, Australia
www.ignss.org

ENC 2011
29 November-1 December
London, UK
www.enc2011.org

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