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Coordinates

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A MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

SATELLITE NAVIGATION

Truths & Myths

The datum debate continues

A cGIT publication

Articles

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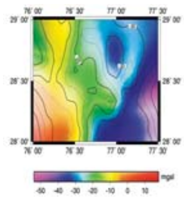

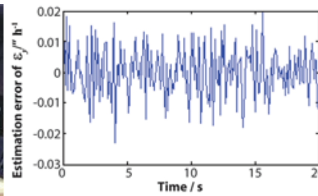

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This issue of Coordinates is of 44 pages, including cover.

Blurred IMAGES

Finally, Google agreed.

Agreed to blur the pictures of sensitive Indian establishments.

Recently, Google Earth shocked many.

Many took the development as the deathblow to the issues like "non-accessibility/non-availability of spatial information".

However, many got worried, more than ever before, about the security implications.

The issue was more important as many contended that "such exposures" were selective in nature and not for all the countries.

Many countries were apprehensive and concerned about the fallout.

Many were caught off guard and fumbled in formulating their response.

Hopefully, this step by Google may address the security concerns of India to an extent, raised by no one else but by the President of India himself.

Ironically, the adversaries and terrorists do manage to get hold on sensitive information of their needs. Regardless.

So, the challenge will continue on how to restrict the access of spatial information to ill-intentioned users.

However, it is also a challenge, in a given scenario, to provide a hassle free access to spatial information to genuine users.

Unfortunately, they cannot 'manage' when they need.

Bal Krishna, Editor
bal@mycoordinates.org

Satellite Navigation – Truths & Myths

It is a myth that Galileo will give Europe independence of the US in satellite navigation

PROFESSOR DAVID LAST

Today's professional navigators may well be the last. As recently as a generation ago, navigation was almost solely the specialised art of a small number of highly-skilled people. They wore uniforms with emblems on their shoulders. They had years of training. They used complex, expensive, equipment. They bestrode the bridges of ships and the flight decks of the large commercial aircraft and took star shots.

Fig 1
From: May, V., 'The first handheld aviation navigator', Navigation News Nov/ Dec 2001, pp8-9..

Then, quietly, a revolution started in the world of navigation. The first phase of the revolution brought lower cost, smaller, higher performance navigation equipment. Amateur sailors and aviators got technology more powerful than professional equipment, and very much cheaper: Decca Navigator and Loran-C sets for yachts, for example (Fig 1 & 2).

The second phase of this revolution was driven by GPS. Navigators, the early adopters of satellite navigation, were rapidly followed by surveyors, geodesists, desert travellers - people with at least loose connections to navigation. But then came, farmers, motorists, truckers, people seeking not so much the high peaks of the great outdoors as the delivery bay at McDonalds! Soon, these non-navigators outnumbered the navigators. Global navigation systems stopped being primarily about navigation; they became simply public utilities.

And now we are entering a third phase of this revolution, where the utility that is Global Satellite Navigation becomes universal and largely invisible. The trigger for this phase was the US government's requirement that cell-phone networks should automatically identify the locations of users who call the emergency 911 number. Many networks chose Assisted-GPS (A-GPS) technology, near-instantaneous location measurements using a GPS receiver inside the handset, assisted by data passed to it over the cellular system (Fig 3). This works, and the networks can now locate their users.

Your phone can tell you where you are, download a map for you, guide you to your destination; it can locate the nearest police station, or hospital, pubs for young men and toilets for elderly gentlemen. It can give you tourist information, tell you of traffic problems ahead. Phones can track your children or your girlfriend, or your boyfriend! Of course, think of the Internet and spam: as you walk down a street, your phone will soon try to entice you into sleazy bars, dubious cinemas, or houses of ill repute!

We are entering a third phase of revolution in the world of navigation, where the utility that is Global Satellite Navigation becomes universal and largely invisible

Worldwide, there will be soon be hundreds of millions of new users of global satellite navigation systems, GNSS. Most of them will neither know nor care that they are using a satellite navigation system. Our sophisticated navigation technology will simply

Fig 2

From: www.garmin.com/marine

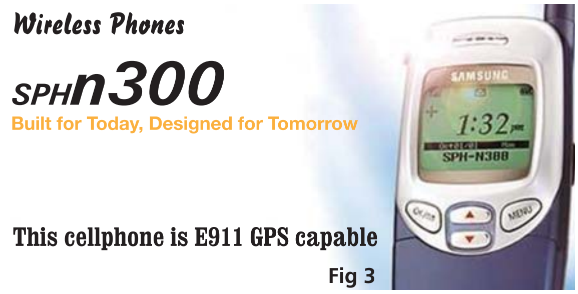


Fig 3

From: www.cellphonesforbusiness.com/ www.samsung.com


Fig 4

Dice is 1mW GPS jammer

have become a location sub-system of a low-cost consumer product.

Have navigators, institutes of navigation, or national governments yet come to understand this new reality? Do we not still think in traditional navigation terms, of ships and aircraft alone? Look, for example, at how we are responding to the current threat of the possible loss of satellite navigation.

On September 10, 2001, the day before 9-11, the Volpe Report was published. This US government document speaks in clear terms of the risks the US takes if GPS becomes its only means of navigation, or (as it is becoming) the only source of the precision timing that synchronises US telecommunications networks.

The risk is partly from interference, unintentional or intentional. Volpe says such interference hazards can be reduced, but never eliminated. And with US transportation relying increasingly on GPS, losing it could cause severe safety and economic damage to the nation, unless those threats are somehow mitigated. The report says that GPS is becoming a tempting target for individuals, groups, or countries hostile to the US. GPS can be denied by jamming, and receivers can even be spoofed into producing hazardous, misleading information. So, the Volpe Report calls for awareness, planning, and supplementing GPS with backup systems in critical applications.

The US Department of Transportation reacted to the report promptly, with detailed consideration of its implications for each mode of transport: land, sea and air. In Europe too, the impact of the Volpe report on many navigation professionals was profound. But it has had only a limited effect on our national policies. Do we have GPS interference? Well, pilots certainly report areas of GPS signal loss. But jammers?

The little dice in Fig 4 contains a hidden GPS jammer. It radiates just 1mW of power, but it can jam civil GPS out to 125metres, military GPS to about 80metres. The Volpe Report showed that a 1Watt unit, about the size of a cell-phone, could jam out to 10km and prevent receivers finding the satellite signals at 85km. A more sophisticated jamming signal would be effective to maybe 1000km.

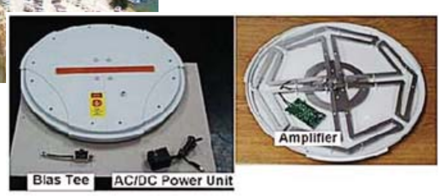
Such a jammer on the roof of a tall building could stop every GPS across a city: car navigators, tracking systems in taxis and fire trucks, and receivers in aircraft within line of sight. If the jammer were left on, and perhaps moved occasionally to make it harder to find, it would begin to affect GPS-timed telecommunications systems. Cell-phone sites, and telephone and data communications that employ local GPS timing, would gradually drift out of synchronisation and fail.

Who would deal with the problem? Would the US Cavalry come riding over the hill? We must ask in each country: who has the equipment to find a civil jammer, the organisation to respond, and the legal powers to enter buildings and search for it? In most countries: no-one.

Jamming problems are real. In the harbour of Moss Landing in California, a couple of faulty TV antenna units on boats radiated interference (Fig 5). Every vessel in the harbour, and up to a kilometre out to sea, lost GPS service. So did every vehicle and every individual. A few GPS receivers actually gave false positions. The problem lasted for months until the cause was tracked down by technically-competent volunteers. There are millions of such TV amplifiers across the world. These units are not designed to jam GPS, but their malfunctioning can result in a 3 km jamming range. Imagine a jammer purpose-built by an expert!

GPS jammers have a lot

Fig 5. Source: Clynch et al, 'Multiple GPS RFI Sources in a Small California Harbor', ION GPS02, Portland OR.



Radio Shack 15-1624 VHF/UHF Antenna

in common with computer viruses. We know about viruses; we live in a world in which a socially-inadequate teenager with acne and no girl-friend, can cause havoc in the Pentagon and panic in the banking system! There are designs for GPS jammers on the Web. Jamming does not take Al Qaeda, it takes a spotty kid in his bedroom. Satellite navigation is like the computer business before the first virus. And we have no McAfee and no Norton!

It could get much worse when people really try to stop satellite navigation. Many European countries now plan to charge road users. Motorists hate the idea, just as they hate radar speed traps. A jammer in a motorist's car could disable GPS road user charging across a city - and at the same time disable GPS for the rest of the population. Who would track it down? How long would that take?

That is the potential problem. The response of each nation tells us a lot about whether they have woken up to the new satellite navigation world. Initially, the UK and other countries, responded to the threat of losing GPS by stating that they required multiple navigation systems for aviation and shipping - the traditional navigation applications. These are indeed safety-critical areas, and governments have responsibilities for them. But there is no sense here of governments recognising the role satellite navigation is now playing in their economies. What about telecommunications timing, mobile phone users and their emergency calls? The UK and other countries are saying that these millions of new users (perhaps 96% of the market) are not critical and do not really need satellite navigation. If there is a GPS problem, they can just go back to doing what they did before.

But they no longer can! Of course, we could lose our car navigators. But whole swathes of industry and commerce have committed to the cost savings and efficiency benefits offered by GPS. Our telecommunications rely on it totally. It is simply too late to go back to what we did before. People do not maintain their old systems alongside the new and pay for both! A recent European report showed that fewer than 40 of 137 GPS applications would remain operational if GPS were lost. So as we commit to the widespread dependence of our industry and commerce and navigation on satellite systems, we need to retain some terrestrial backup.

GPS jammers have a lot in common with computer viruses. We know about viruses; we live in a world in which a socially-inadequate teenager with acne and no girl-friend, can cause havoc in the Pentagon and panic in the banking system!

A leading candidate, suggested in the Volpe Report, is Loran-C, especially the new Enhanced Loran (eLoran). Loran is a terrestrial system with transmitters of hundreds of kilowatts operating at the low frequency of 100kHz. It is in place across all the US and much of Europe and Asia. The strengths and weaknesses of Loran (Fig 6) are very different from those of GPS. GPS is vulnerable to interference because the distant satellites deliver so little power to our receivers. Loran, with its megawatt stations and tall transmitting antennas, is at least 10,000 times harder to jam. Then, microwave signals from satellites and low-frequency signals from Loran prevent single-point failures. On land, where buildings and mountains block GPS signals, Loran travels along the earth's surface, deep into city centres, even into buildings. Like GPS, eLoran is a complete navigation and timing system.

Integrate them together in a single receiver (Fig 7), and eLoran will take over seamlessly when GPS fails.

Loran as a complement to satellite

Satellite	Loran-C
Low powered: vulnerable	High powered: robust
High-frequency	Low-frequency
Line-of-sight: easily blocked	Groundwave: penetrates cities
A navigation and timing system	A navigation and timing system

Fig 6 © David Last, University of Wales, Bangor

Fig 7

© David Last, University of Wales, Bangor

eLoran in that mode, like GPS, works with an accuracy of metres; it delivered harbour entrance accuracy of better than 10m in recent UK trials. Loran has recently been modernised right across the US to act as a backup to satellite navigation and Europe has to decide whether to do the same. Both the US and Europe will shortly set out their future polices on eLoran.

Many Europeans, though, believe that there is a different solution to the problem of GPS vulnerability: Galileo. The European Commission says: "Galileo will be far less vulnerable than GPS, so eliminating most concerns expressed in the Volpe report … because Galileo will use a variety of different and separate frequencies.

Why is Europe is producing a GPS look-alike? Like GPS, Galileo will be a Global Navigation Satellite System. It is broadly similar to GPS, using the same principles and radio frequency bands, so our receivers will pick up both. But they are very different in certain important respects.

GPS started life as a US Air Force "weapons aiming system and force enhancer", and though it now has both military and civil roles, at times of crisis the US military requirement always prevails. Galileo was a wholly civil concept; but gradually questions of its possible military role have emerged, and are now a hot topic. GPS belongs to a single nation, and the rest of us use it on terms that suit US interests. Galileo belongs to the many nations of the European Community who have sought the active participation of other nations.

There are important technical differences between the two systems: frequencies, codes, time standards, modulations, and geodetic frameworks. GPS is free of charge. With Galileo, the user pays for additional services. One is run by the military, the other is to be a public-private partnership. And, of course, GPS is a mature system, the first satellite launched in 1978, a stunning success. Galileo is still essentially a proposal; only the first test satellite has yet been launched. The first true Galileo satellite will be a full 29 years behind GPS!

Tensions between US military control of GPS and its growing civil use led to the imposition of Selective Availability (SA), the intentional reduction of the accuracy available to civil users. Despite SA, civil GPS use flourished, and Differential GPS (DGPS) was developed to give high accuracy (Fig 8). In DGPS, a receiver at a differential reference station measures where GPS says it is. It knows where it truly is, so it can compute and broadcast corrections for the GPS errors to users in the region, who apply them and so get metre-level or better accuracy. The US Coast Guard were pioneers of DGPS. So, by the mid-90s we had the bizarre situation that the US government had spent some $20 billion creating

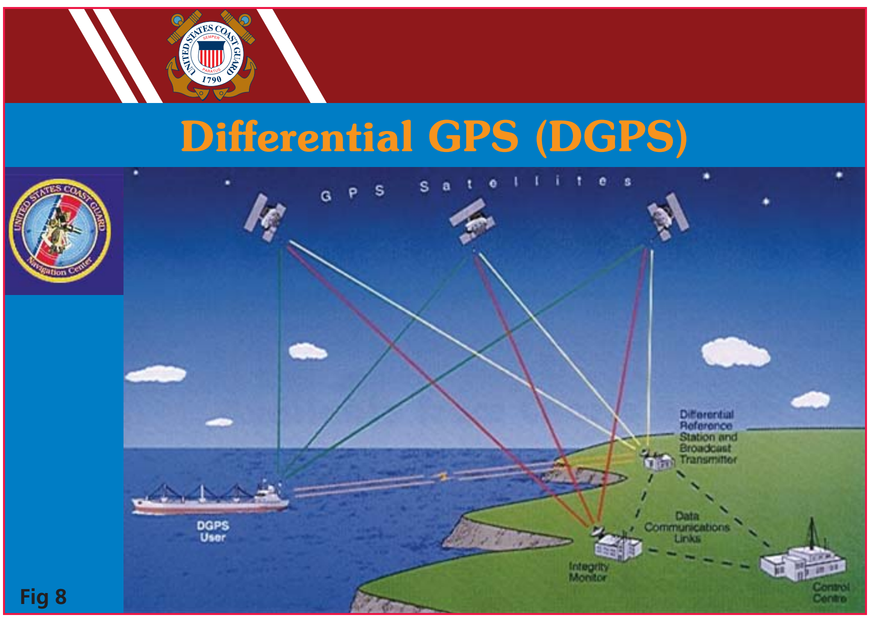


Fig 8

Picture: Admiralty List of Radio Signals
© David Last, University of Wales, Bangor

a highly-accurate navigation system, millions more to deny that accuracy to most of the users, and was spending yet more on DGPS. This not only defeated SA, but actually gave civil users higher accuracy than the military GPS that SA was there to defend!

This could not go on! Under pressure from civil users and manufacturers, the US announced that it would switch off SA and replace it with a "capability to prevent hostile use of GPS … to retain US military advantage in a theater of operations without disrupting … civilian uses outside the theater". At the same time, the US said it wanted to encourage acceptance of GPS worldwide. So, the drivers of US policy were now absolutely clear: to prevent use of GPS by its enemies; and to maximize commercial returns to the US.

Europe read clear messages in US statements. When the US said GPS was now an integral component of the global information infrastructure, with a myriad applications, that had "generated a huge US commercial … industry", Europe wanted a slice of that action. And, since US policy was also to "limit availability of their radionavigation systems in the event of a real or potential threat of war or impairment to their national security", Europe's access to GPS depended upon US decisions. Europe might well disagree with the US about national security, as recent world events have shown. Europe's response was Galileo.

Galileo will have an Open, free, service for everyone. There will also be a paid-for Commercial Service offering higher accuracy, a higher data rate, and extra messages, plus a separate Safety-of-Life service, a search-and-rescue facility and an encrypted Public Regulated Service (PRS) for government agencies and law enforcement. Galileo is designed to warn users of satellite failures immediately; GPS does not. Galileo promises legal service guarantees to commercial and safety-of-life users; GPS has no legal guarantees. Galileo will use a commercial service provider, and – in theory at least – will remain a civil system.

The Galileo project is now 12 years old. It is still awaiting agreement as to who is to run the commercial services. The market analysts predicted a huge rising global satellite navigation business, with mobile phones and car navigation as the major sectors, and traditional navigation a tiny part of the market. But what is unclear is how much of this market Galileo will capture, just who is exerting the market pull for Galileo, and who will pay for its services. There is no doubt: the world wants satellite navigation, but will it pay for Galileo, when GPS is free?

GPS is free of charge. With Galileo, the user pays for additional services. One is run by the military, the other is to be a public-private partnership

What is clear is that the great attraction is actually GPS-plus-Galileo, 60 satellites not 30, with completely-integrated receivers. But to deploy a combined system like that, Europe needs the co-operation of the United States. Many Americans, once they had figured out what Galileo was (and separated it from NASA's Jupiter probe also called Galileo) welcomed it with open arms. They saw that it would provide 60 satellites not only for Europe, but also for the US. Doubling the number of satellites meant more accurate car navigation in city streets, more signals in urban canyons, less scintillation noise at low latitudes, and two separate control segments giving reduced vulnerability. Galileo offers two-frequency operation, 4 years ahead of GPS. Everybody wins!

But to others in the US, Galileo was a threat that directly challenged US ambitions to lead the world industry. Worse, it challenged US national security: why pull GPS out of a theatre of conflict if the bad guys in the black hats simply keep on coming at you, using Galileo? So, the US declared that it had to be able to remove all satellite navigation systems. That meant either Europe's agreeing to withdraw Galileo on a US demand, or the US would jam Galileo!

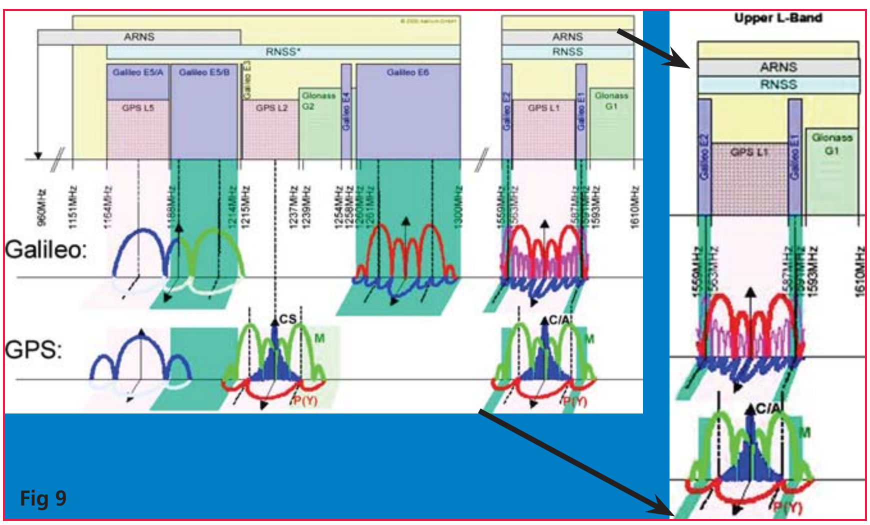


Fig 9

Godet et al, 'Galileo spectrum and interoperability issues' GNSS2003, Graz, Austria April 2003

The country that has benefited most industrially from GPS is not the US, but Japan

And that linked into the frequency question. Channels for GNSS are scarce, obliging Galileo to share frequency bands with GPS. That is essential, too, if we are to have low-cost combined receivers. But then, Galileo and GPS must not interfere with one another. Preventing interference required some spectacular communications engineering, with Galileo's signals being wrapped intimately around the GPS signals, yet never touching: a sort of safe sex in the frequency domain (Fig 9)!

But then a problem arose: the Europeans laid the Galileo PRS secure signal over the GPS encrypted military signal, the M-Code. It appeared that PRS would probably not interfere with M-code. But if the US wished to jam Galileo PRS, it would be also jam its own military code! So now there was a major dispute between the US and Europe! NATO joined in on the US side, arguing its need "to deny a potential adversary's access to … any … satellite navigation services". The row came at a time of heightened tension between the US and Europe and led to strong words. Was Europe to become, as President Chirac of France claimed, "a vassal" of the United States? These matters had to be resolved if Galileo was to have a commercial future, sharing frequencies and receivers with GPS. And both sides needed a security and non-interference agreement.

Happily, after many arguments, Europe agreed to move its PRS signal away from the M-Code. So now, one can jam either the Galileo and GPS Open services, or the PRS, or the M-Code, in isolation! More positively, Europe and the US agreed common signal structures, and inter-operable timing and geodetic standards, opening the door to a combined system. They also agreed on open trade: that neither side would mandate the use of its own system alone. And they set a common goal - the best possible GNSS for users around the world.

Yet, for Galileo, great challenges remain: will it be funded to completion; who will take on its legal liability and what will that cost; how much control will be ceded to nations outside Europe; how much access will Galileo have to GPS technology, where that is ahead of Europe's?

And how much now remains of Europe's dream of independence of the US in satellite navigation? Combined receivers and national security have required cooperation with the US, not competition and they have agreed a level commercial playing field. But sharing frequencies and codes means something very important: that when civil GPS is lost to interference or jamming, Galileo may be too. Independence of the US? Is there any realistic scenario in which GPS would be withdrawn and civil Galileo would continue, independently?

I believe it is a myth that Galileo will give Europe independence of the US in satellite navigation. It is equally a myth that it will necessarily bring to Europe a vigorous new industry. The country that has benefited most industrially from GPS is not the US, but Japan. Operating a satellite system is of little commercial value; you get your vigorous new industry from selling users the equipment they want.

And yet, Galileo will achieve so much more than those dreams of independence that have convinced European politicians to fund it. This is the future of Global Navigation. With a reinvigorated GLONASS, new satellites from Japan and China, and global financial and technical collaboration, the impact of Galileo-plus-GPS will exceed the sum of its parts. Backed up with carefully-chosen terrestrial systems such as eLoran will create robust navigation for all modes of transport - a goal of immense value that is almost within our grasp!

David Last is a Professor Emeritus in the University of Wales and President of the Royal Institute of Navigation. He is a Chartered Engineer who has published many research and policy papers on navigation systems and acts as a Consultant on radio-navigation and communications to companies and to governmental and international organisations. David is an instrument-rated pilot and user of terrestrial and satellite navigation systems.

Determination of local gravimetric geoid

A case study of Delhi area

SK Singh, Brig (Dr) B Nagarajan, PK Garg

The demand for a high resolution geoid model has grown substantially during the last few decades especially after inception of Global Positioning System (GPS). Many countries across the world have already developed their own geoidal model which serve as the means of deriving orthometric heights from GPS observations. The impact of GPS on surveying application is undeniable. More so, this revolution has not been confined to the surveying community, but has extended into mapping, navigation and Geographic information system (GIS) areas. During the last few years, we have been witnessing the wide spread adoption of GPS with an equivalently vibrant range of accuracy requirement. Many of these applications require accurate vertical positions.

The task of transforming the ellipsoidal height obtained from GPS technique to the orthometric height has prompted geodesists around the world to determine the high precision geoid undulations, for their region of interest. In India the present day nation wide geoid was computed a long time back and based on astro geodetic observations with respect to Everest spheroid. It has various limitations and does not have any significance as far as GPS solutions for orthometric height is concerned.

Present study was taken up to validate the results of orthometrc heights derivation in a pilot project of large scale mapping of a part of Delhi through Airborne Laser Terrain Mapping(ALTM) Technique. A fairly dense gravity anomaly data consisting of about 160 uniformly distributed points covering a block of 1° X 1° including National Capital Region(NCR) of Delhi was used in the geoidal modelling process .The study was aimed at to analyse approach of data preparation and treatment procedures and a evaluation of test results obtained from the analytical solution of Stokes' integral with appropriate Kernel modifications.

Gravimetric Geoid and GPS

The geoid can be broadly defined an equipotential surface of Earth's gravity field that closely approximates with mean sea level (MSL) neglecting long term effect of sea surface topography (SST). The fundamental relationship between the geoid and reference ellipsoid is given as:

$h = H + N$

Where h → ellipsoidal height

H→ orthometric height Geoid

N→ separation between geoid ellipsoid termed as geodial undulation.

The relationship can be more clearly shown in figure 1.

Geoidal undulation (N) is required for many geodetic and surveying applications the most notable of these being the need for converting GPS-derived ellipsoidal height (h) to orthometric heights (H). The reference surface for orthometric heights was tradionally defined by the MSL measured at one or more tide gauges and realized through geodetic levelling in India for example the datum for orthmetric height was defined in 1909 using the MSL data furnished from 9 tide gauges sites at Karachi, Bombay, Karwar, Beypore, Cochin, Nagappattinam, Madras, Vishkhapatnam and false point (Burrard, S.G, 1910). The datum defined in 1909 is still in use and suffice most of the practical applications.

The geoid undulations (N) may be computed in a simple manner by doing GPS observations in order to determine the ellipsoidal heights at all levelling bench marks. However if heights of some other points is required to be given it may not be possible to extrapolate the GPS- levelling heights differences. In this case gravimetric information may be used to bridge the gap through determination of local gravimetric geoid. In a broad sense

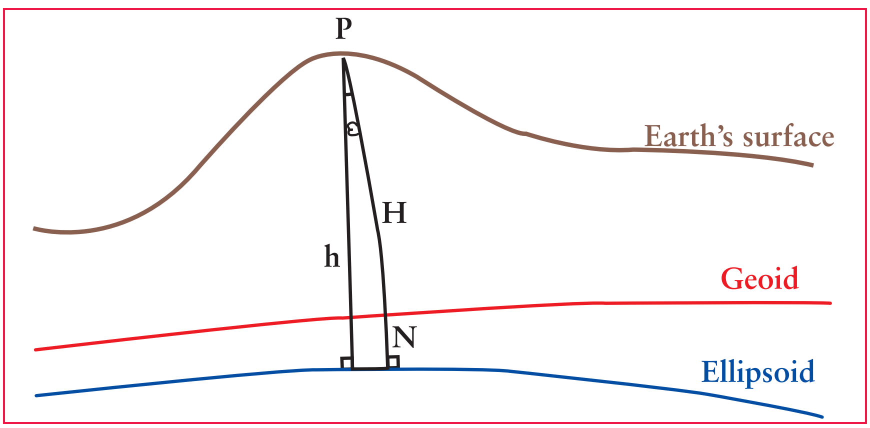


Fig 1. Geoid – Ellipsoid Relationship

geoidal surface is that undulating surface along which the potential remains the same.The undulations of the geoid are not the same as, but are affected by the variations in topography. Because of this complexity, high resolution gravimetric geoid models and associated interpolations software have been developed to support GPS height conversion.

Geoid computation procedure

The geoid determination process employed Stokes' integral formulae which allows a pointwise calculation of gravity field quantities and thus provide the possibility of an arbitrarily high gravity field resolution which depends only on data coverage and quality. Utilizing local gravity anomalies as the primary data set classical solutions is aimed at the determination of geoid height.

Purely gravimetric calculations of geoid heights is hampered by long-wave systematic data errors and by inhomogeneous spatial resolutions and accuracy of the local gravity data. The global geopotential models such as EGM96(Lemoine et.al.,1998) generally provides the long wave part of the gravity field and dense local gravity data together with high-resolutions digital elevation models leads to a combined solution that can be applicable to a limited region, where data smoothening techniques are used by considering the terrain effect. A remove compute- restore technique(Schwarz et.al.,1990) is applied in this study which includes the following steps.

1. Calculation of necessary corrections e.g. gravity formula corrections for free-air anomalies data to obtain corrected gravity anomalies Δg_{cor}
2. Reduction of the gravity anomalies Δg_{cor} by the anomaly part of the global model to a degree of expansions m and obtain the reduced anomalies Δg_m
3. Smoothening of the anomalies by applying the terrain corrections Δg_t.
4. Griddings of the residual gravity anomalies
   $\Delta g_{res} = \Delta g - \Delta g_{cor} - \Delta g_m - \Delta g_t$
5. Application of Stokes formula on the residual gravity anomalies resulting on residual geoid heights Nres
6. Restoration of the effect of the global model and the terrain to the residual geoid heights:
   $N = N_{res} + N_m + N_t$

A schematic diagram of the general computation procedure is given in figure 2.

Stokes Integration:

The Stokes integral is one of the fundamental and most important formulae in physical geodesy. It was derived by G.G. Stokes in 1849 to compute geoid undulations N from terrestrial gravity anomalies (Heiskanen and Moritz, 1967) :

$$N = \frac{R}{4\pi r} \iint_{\sigma} \Delta g S(\psi) d\sigma \qquad (1)$$

Where R Mean earth radius
γ Mean normal gravity for the earth
σ The sphere of integrations
S(ψ) Stokes` function
Δg Free air gravity anomalies
dσ Element of surface area on the sphere
Ψ Surface spherical radius (ψ) between two point on the sphere and is given by
$\cos\psi = \sin\Phi \sin\Phi' + \cos\Phi \cos\Phi' \cos(\lambda' - \lambda)$

Where Φ,λ are geographical coordinates of computation point and Φ`and λ` are the coordinates of surface element dσ.

The Stokes` function in closed form is defined as,

$$S(\psi) = \frac{1}{\sin(\frac{\psi}{2})} - 6\sin\frac{\psi}{2} + 1 - 5\cos\psi - 3\cos\psi \ln(\sin\frac{\psi}{2} + \sin^2\frac{\psi}{2}) \qquad (2)$$

The Stokes` formula in its original form suppresses the harmonic terms of degrees one and zero in N and it holds only for a reference ellipsoid that;

(1) Has the same potential as the geoid.
(2) Encloses a mass that is numerically equal to earth's mass.
(3) Has its centre at the centre of gravity of the earth.

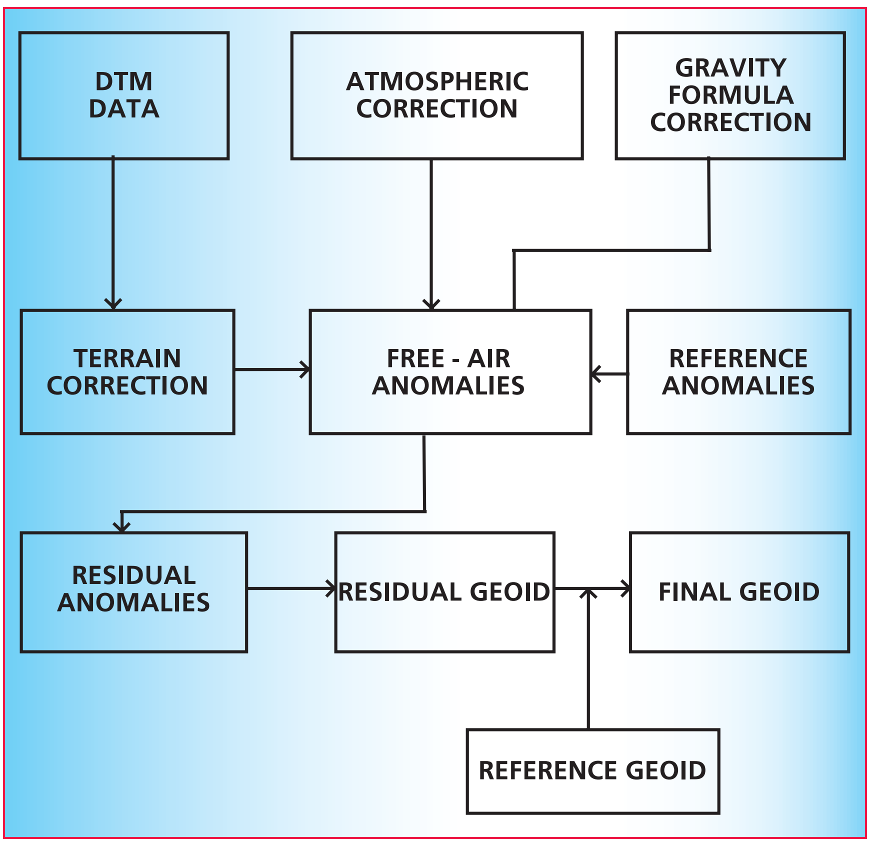


Fig. 2.General computation procedure of Local Geoidal Modelling process

Data preparation

Free air gravity anomoly data

Free air anomaly values of test area were compiled from observed gravity database maintained by Geodetic & Research Branch (G&RB) , Survey of India. The compiled data base comprised of about 160 gravity values spread uniformly over the test area (see fig.3). The datum for all Indian gravity measurement is a network of local base stations which were tied to the International gravity standardization Network 1971 (Morelli et. al. 1971). It is not known whether any variant of the tidal correction was applied to the local gravity observation and also the given elevations of gravity stations were of variable quality. Some of the gravity observations were done on benchmarks of Indian levelling network whereas for a large portion of gravity stations the elevations were computed based on barometric levelling which can be in error of the order of ±2 – 4 m. Since the gravity anomalies values were based on International Gravity formula (1967) therefore to bring them in the Geodetic Reference System 1980 (GRS80) the following transformation was applied (NGS, 1986).

$\Delta g_{1980} = \Delta g_{1967} - (0.8316 + 0.0782 \sin^2 Ø - 0.0007 \sin^4 Ø)$

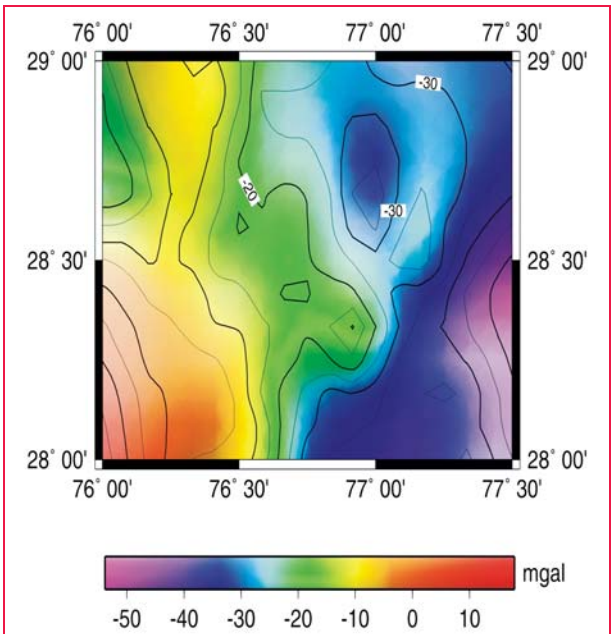


Fig 3. Distribution map of free air gravity anomalies

The converted values were used in subsequent computations of geoid model.

Digitial elevation model for terrain correction

Since as on today no nationwide digitial elevation model (DEM) on appropriate scale is available, a local DEM was computed based on about 130 spot heights in the area. These elevation data have been gridded by using least square collocation (LSC) technique with second order Markov covariance function(Fig.4(a)). The DEM was generated in a grid of 15 X 15 arc second and tested for observed heights versus the interpolated heights. In general these spot heights were found to be in good agreement with the interpolated DEM heights.

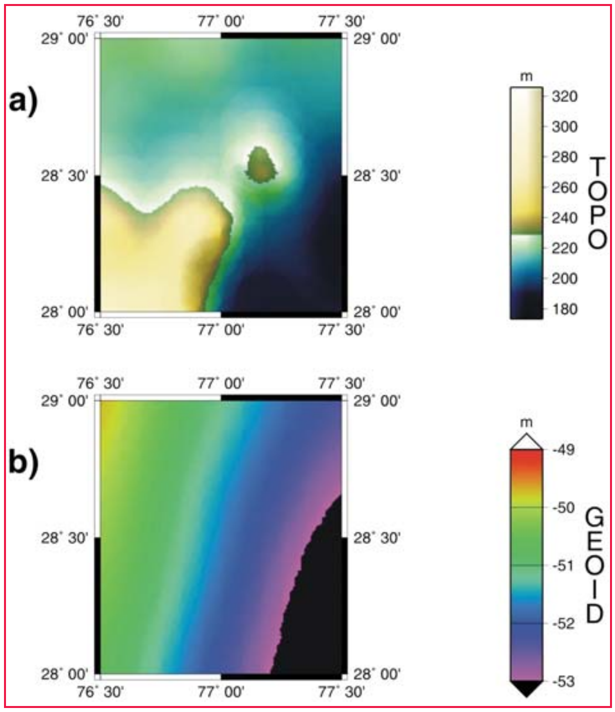


Fig 4. Topography and Gravimetric geoid For Test Area

Methodology

The methodology for geoid computation was based on remove –compute – restore technique as described in sec.2. and can be summarized as follows:

- Remove the long wave length part of EGM96 global geopotential model and terrain effect from the observed free air gravity anomalies to derive residual gravity anomalies(Fig.5).
- Compute the residual undulations NRES of the geoid by numerical integration of Stokes` integral (Eqn.1) using reduced gravity anomaly data.
- Restore the long wavelength effect NEGM96 and residual terrain effect NRTM to get final geoidal undulation N that is: $N = N_{EGM96} + N_{RTM} + N_{RES}$

Computation of geoidal height at a given point with respect to EGM96 (N_{EGM96}) is quite simple using the EGM96 spherical harmonic potential Coefficient set and spherical harmonic correction coefficient both complete to degree and order 360. However the procedure for computation of indirect effect from local topography(N_{RTM})

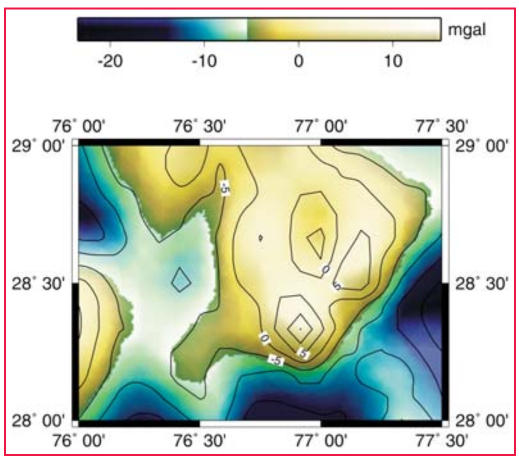


Fig 5. Residual Gravity Anomalies

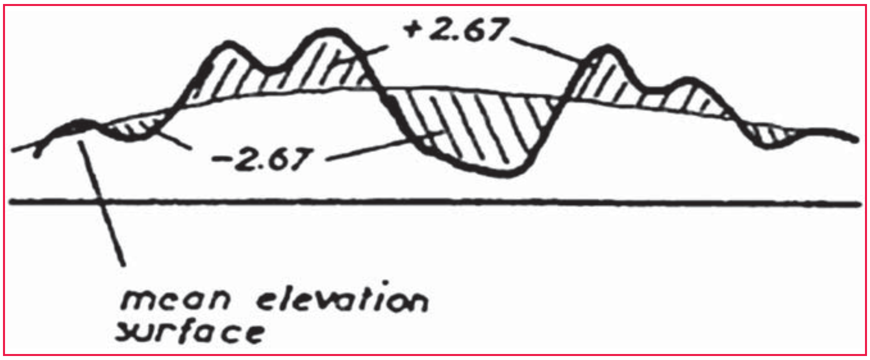


Fig. 6. RTM effect principle:Gravitational effect of the topographic mass distribution with respect to mean elevation surface.

and Residual undulation NRES using Stokes` integral is little complicated and required to be discussed in detail.

Terrain correction

Computation of N_{RTM} is done relative to the mean elevation surface (fig.6)

In case of remove – compute – restore technique, substracting the contribution of reference global geopotential model from the local terrestrial gravity data also include the effects of the global topography ; therefore substraction of further topographic effect may introduce long wave length effects into the residual potential. To avoid this only short wavelengths of the topographic effect may be used, which is termed as residual terrain model (RTM) effect(Forseberg,R,1994) . The RTM terrain effect may be computed in a spherical cap around the computation point, provided the cap is sufficiently large so that the remote residual topography has a negligible effect.

In this study the mean elevation surface was determined from the DEM data by applying the moving average method. The RTM gravity terrain effect in the planner approximation given by a volume integral:

$$\Delta g_{RTM} = G\rho \iint_{-\infty}^{\infty} \int_{z=href(x,y)}^{z=h(x,y)} \frac{(z-h)\,dx\,dy\,dz}{\left[(x-x_p)^2+(y-y_p)^2+(z-h_p)^2\right]^{\frac{3}{2}}} \quad (3)$$

Where h are the heights of topography, G is the gravitational constant and ρ is the mass density taken as 2.67 gm/cm^3 in the computation. The computations of Δg_{RTM} were done in space domain prism integration by Fast Fourier Transform (FFT) method using the dense height data.

Modification of kernel

Modification of Kernel S (ψ) in Stokes` formula forms an important part of geoid determination process due to the fact that long wave-length systematic errors in gravity data can produce large geoid errors. These systematic errors can be avoided by modifying the classical Stokes` Kernel in an appropriate manner. There are different ways of modifications, however in our study we used the modification suggested by Wong and Gore (1996).

As per the technique the spheroidal Stokes' kernel S(ψ) in equation (1), which is implicit to the Stokes' formula, can be modified simply by removing the appropriate-degree Legendre polynomials [*Pn*(cosψ)] from the closed form of the spherical Stokes' Kernel (Eqn.2).

$$S^{M+1}(\psi) = S(\psi) - \sum_{n=1}^{M} \frac{2n-1}{n-1} P_n(\cos\psi) \quad (4)$$

Where is the spherical distance between the computation point and integration points. We may choose any degree of modification to our choice which permits the ultimate geoid to best fit the GPS-Levelling undulations. At the same time the modification approach should be applied in combination with capsize radius $\psi = \psi_m$ as both the reference geoid EGM96 as well as local gravity data may have errors and therefore the difference between the two geoids i.e. gravimetric and GPS-Levelling with different degrees of modifications does not necessarily equal to zero.

Thus kernel modification and capsize assumptions provide the means of optimising the solution of Stokes` integral in determination of local geoid.

Geoid model construction

For computation of geoid the degree of Kernel modification in Eqn. (4) was chosen to be m=360, which is same as the degree of reference global geopotential model EGM96. Eqn. (1) when applied over a limited spherical cap of radius ($\psi_{\circ}$=0.5°) about each computation point leads to the following approximation of geoid height

$$N \approx N_M + \frac{R}{4\pi\gamma} \int_{\sigma_0} S^{M+1}(\psi,\psi_0)\Delta g^{M+1}\partial\sigma \quad (5)$$

The concept of spherical cap of limited spatial extent in analytical solutions of Stokes' integration was implemented simply by setting the value of to zero out side the cap region. The final geoid was constructed based on the methodology described in section 3. The reduced gravity data was arranged in a grid using Least Squares collocation (LSC) technique. Geoidal heights were computed by applying the generalized Stokes' scheme(Eqn. 5) using spherical cap of radius 0.5°. NRTM was computed by planar approximation implemented using FFT technique on the 0.5 Km basic resolution grid. Finally, NEGM96 was added to NRES and NRTM to obtain the final geoid (Fig. 4(b)). Table 1 below shows the statistics of the various component computed at the different stages of the model construction

Looking at the table-1 the effect of Residual terrain model (N_{RTM}) is almost negligible and only shortwave residual gravity anomalies contributes to reference geoid i.e. EGM96. However the effect, as evident from the table-1 is order of 35-55 cm which is a minor quantity in comparison to the total geoidal undulation (≈-53 m). Thus EGM96 geoid is very smooth in the region and almost fit in to the local geoid having only the minor short wave length variations.

Table 1. Statistics of the components of gravimetric geoid at different stages of model construction

Components	Mean	Std. dev.	Min.	Max.
Δg	-22.61	11.381	-46.833	10.365
Δg_{RTM}	0.165	1.686	-3.41	10.410
Δg_{res}	-4.83	6.05	-21.33	14.50
N_{res}	0.445	0.051	0.359	0.555
N_{RTM}	0.001	0.011	-0.023	0.041

Note: Δg and N are measured in mgal and meters respectively

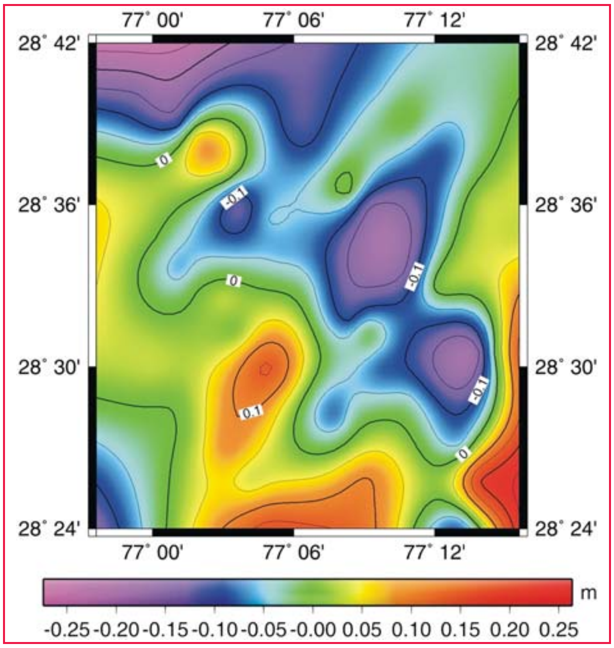


Fig 7. residual plot of GPS/Leveling differences and Gravimetric Geoid undulations

Evaluation of Geoid Model

Differences between the GPS derived ellipsoidal heights and the levelling heights of bench mark of national control network are generally being used for geoid evaluation. In present study the GPS/levelling differences were derived by making GPS observations on 50 nos. of stations and connecting them to bench marks of Indian vertical control network by running precision leveling lines. GPS data was processed using BERNESE Software Ver.4.2 and an accuracy of derived ellipsoidal height of the order of few cm has been achieved. None of these stations was included in the geoid modeling process. The quantities to compare are the geoidal heights from the gravimetric geoid Ngrav and the corresponding geoidal height NGPS from GPS/leveling observations. The misfit ε

$\varepsilon = N_{GPS} - N_{grav}$

includes datum differences, systematic errors and subsidence /uplift in the levelling, as well as errors in the gravimetric geoid. The statistics of the GPS/levelling differences and heights from gravimetric geoidal model have been presented in Table 2 and Fig. 7 shows the contour plot of the differences.

The above results clearly show a close matching between the gravimetric geoid and GPS/leveling differences and probably described the advantage of using dense gravity data. There is hardly any longitudinal variations noticed for the geoid but it has shown the traces of northward gradual slope which may be evident more clearly when computations are taken for a larger region. Though the results still contain the systematic differences between local levelling network and the gravimetric geoid but major contribution of these errors has been nullified due to the fact that test area is considerably small and terrain effect is almost negligible because of smooth topography of the region.

Conclusions

This paper has described a brief review of some of the important aspects involved in computation of gravimetric geoid model in Indian context. The use of generalized scheme along with modified Stokes Kernel in remove-compute-restore technique has been successful to a great extent in computation of geoid model from dense gravity anomaly data of Delhi area.
The study has firmly shown that EGM96 can be effectively used for gravimetric geoidal modeling in India notwithstanding its own shortcomings provided that the other aspects of the methodology are explicitly designed and followed carefully. The procedure of analytical solution of Stokes integrations with spherical cap of radius of o.5° using dense gravity data has worked well and achieved an accuracy, in absolute sense, of the order of 20 cm as determined from comparison with GPS/leveling differences making it an alternative to conventional method of leveling, suitable for most of the mapping applications. However a significant size of errors in GPS determined ellipsoidal heights is always expected from the various error sources. Even with a very detailed error modeling of all the possible source effects the achievable accuracy of GPS ellipsoidal height is always considered to be less than the horizontal positional accuracy. Hence the extent of misfit between the gravimetric geoid and GPS/levelling difference should not be always viewed entirely due to error in gravity measurements or inadequate geoidal modelling procedure.

Table 2-Statistics of GPS/Levelling & Gravimetric geoid

	MIN (m)	MAX (m)	MEAN (m)	STD. DEV (m)
GPS/levelling	-52.991	-51.913	-52.487	0.268
Grav.geoid	-52.632	-51.554	-52.632	0.290
Diff (ε)	-0.172	0.189	-0.220	0.083

Acknowledgements

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PCGIAP workshop

Integration of built and natural environmental data within national SDI initiatives

As part of the 17th United Nations Regional Cartographic Conference for Asia and the Pacific (UNRCC-AP) held in Thailand in September 2006, Working Group 3 of the Permanent Committee for GIS Infrastructure for Asia and the Pacific (PCGIAP) organised a one-day international workshop (21st September 2006) on the 'Integration of Built and Natural Environmental Datasets within National SDI Initiatives'. The workshop was conducted with the support of the Centre for Spatial Data Infrastructures and Land Administration, the University of Melbourne.

The workshop aimed to facilitate and better understand and describe:

- History and existing work related to the integration of built and natural environmental datasets and related National SDI initiatives.
- Capacity for and policies relating to data integration of cadastral and topographic datasets.
- Institutional support for and barriers against data integration of cadastral and topographic datasets.
- The technical, jurisdictional, institutional, legal and land policy perspective surrounding the integration of built and natural environmental datasets, in particular cadastral and topographic datasets, in a National SDI.
- Countries experiences and initiatives in integrating data in order to identify best practice.

Over 40 people from 18 countries and organisations attended the workshop.

The workshop began with a keynote and welcome by Prof Ian Williamson, the Chair of WG3 who highlighted the importance of the integration of built and natural environments internationally and the role that this plays in terms of meeting sustainable development objectives. The workshop then continued with a presentation by Dr Abbas Rajabifard, the Research Coordinator of PCGIAP-WG3, who reviewed and presented the development of a three year research project through collaboration between WG3 and Melbourne University titled "Integration of Built and Natural Environmental Datasets within National SDI Initiatives". This included an overview of the major aim of the project, which is to develop a model, framework and associated tools for data integration capable of being used in diverse jurisdiction.

An overview of the International Case Studies being utilised as part of the research project on data integration, which are being progressed through the use of an integration template, were presented by Mr Andrew Binns from the University of Melbourne. This template enables the discovery of information from case study countries on activities and issues in data integration including spatial information policies and SDI activities, laws and regulations, infrastructure implementation, institutional arrangements, integration issues and human resource and capacity building.

A focus on key data integration issues and activities related to case study countries within the PCGIAP-Melbourne University Data Integration Project was presented by Mr Hossein Mohammadi, a PhD candidate from the University of Melbourne. This presentation outlined the key legal, institutional, social and policy issues that need to be taken into account in order to technically integrate datasets. This was followed by an overview of some of the actual technical issues hindering integration.

An invited report was then presented by Prof Stig Enemark on the "Integration of natural and built environment data – the experience of Europe with a focus on Denmark". Prof Enemark discussed the development of the INSPIRE initiative in Europe which is both a top down and bottom up approach to the development of a European SDI.

The second session of the Workshop was allocated to the presentation of Country Reports on SDI and data integration activates by participating countries, based on the WG3 integration template. In this session, reports from Brunei Darussalam, Indonesia, Japan, Malaysia, Denmark, the Philippines, Singapore and New Zealand were presented followed by a short comment from other countries and organisations attending the Workshop, including Germany, Cambodia, Fiji, WHO and INSPIRE.

A short discussion was conducted on the impact of issues presented by both country and organisation representatives. This was summarised and fed into the final outcomes session of the Workshop.

Workshop Outcomes

Issues were split into two levels, the first being at a country level which includes the ability to effectively combine data within nations and the second being the importance of the development of the GSDI to help integrate and access data from across the globe to ensure global interoperability. It was noted that in most cases 70% of time is spent on integrating and preparing data for use, with only about 5% being spent on actual decision making. This shows the important need for the development of an effective integration framework and associated tools in order to streamline the integration process in order to increase the amount of time spent on decision making.

Discussion also centred on the importance of providing seamless data integration within the coastal zone or land-sea interface. This is especially relevant for countries within the Pacific region and archipelagic states such as Indonesia and the Philippines who rely on the marine environment as a source of food and income through industries such as fishing and tourism. The utilisation of spatial data for planning and decision making does not stop at the high water mark, and this is reflected in the increasing activities and complexities in coastal areas requiring integrated information for sustainable development and good governance.

The major issues and challenges highlighted during the discussion session are listed in the table below, separated into technical, institutional, legal and social categories.

From these issues and challenges, the participants discussed, made suggestions and agreed on two resolutions which outlined the major recommendations to be made to the UNRCC-AP from the Workshop. Resolution 1 focussed on the management of the spatial dimension of the marine environment including the ability to integrate data at the land-sea interface. The second resolution focussed on the challenging role of utilising an integration framework within SDI initiatives to support spatially enabling governments. This second resolution focuses on the use of location to organise government information and business activities, of which integrating built and natural environmental data is an integral component. Both of these resolutions where then taken to the 17th UNRCC-AP conference and were fully ratified.

- **Resolution 1** - Marine Administration - the Spatial Dimension
- **Resolution 2** - SDI to Support Spatially Enabled Government

As a result of the outcomes of the Conference, PCGIAP-WG3 has aligned its vision and workplan for the next three years towards the implementation of these resolutions and has changed its name to Working Group on Spatially Enabled Government. This WG (Spatially Enabled Government) now aims to assist member nations of the Asia Pacific region to work towards implementing the resolutions within the individual countries as well as the region as a whole. Working Group 3 (formerly named Cadastre) was originally responsible for exploring technical, institutional and policy issues regarding the contribution of SDI in designing, building and managing large scale, spatial, people relevant datasets, and in particular their role in cadastral, land administration and marine administration systems.

Further information on the integration project can be found at the dedicated project website http://www.geom.unimelb.edu.au/research/SDI_research/Integrated/ or through the PCGIAP-WG3 web page (www.pcgiap.org).

For further information contact Associate Professor Abbas Rajabifard, Vice Chair PCGIAP-WG3 (abbas.r@unimelb.edu.au).

Table 1 - Issues and challenges in the integration of built and natural environmental data

Issues and Challenges in the Integration of Built and Natural Environmental Data	
Technical	**Institutional**
• Lack of Vertical Topology	• The governance system
• Data Model Heterogeneity	• Collaboration approaches
– Discrepancy in scales and across jurisdictions – Hierarchical approaches	• The historically different perspectives of built and natural data
• Standards and specifications	• Custodianship arrangements
• Attribution Inconsistency	• Lack of awareness among decision makers
• Incompatible formats and data structures	• Inflexible funding models/Pricing
• Reference systems	• Conflicting economic and political priorities
• Lack of an holistic technical data integration framework	• Lack legislative support
• Metadata	• Land-Sea interface
• Data completeness and quality	
Legal	**Social**
• Data security	• The historically different perspectives of built and natural data
• Privacy and policy	• Capacity building
• Intellectual Property (IP), licensing and copyright issues	• Cultural barriers including silo mentality
• Rights, restrictions and responsibilities on data	

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A new approach for SINS stationary self-alignment

A new self-alignment approach based on the measurement of IMU is proposed for SINS on a stationary base.

JIANGBIN ZHOU, JIANPING YUAN, XIAOKUI YUE, JIANJUN LUO

The object of the SINS self-alignment is to determine the direction cosine of the transformation from the body frame to the navigation frame, namely, the elements of initial attitude matrix, using the accelerometer and gyro outputs. As the alignment accuracy affects the accuracy of the navigation system directly, one of the most important requirements of SINS alignment is high alignment accuracy. In many practical applications, SINS alignment also requires high alignment speed and the capability of self-determination, especially for military applications.

At present, the alignment model given by Bar-Itzhack and Bermant with the observations of velocity, is widely used in general stationary SINS self-alignment, such as fast alignment proposed by Jiang Cheng Fang and De Jun Wan, multipositon alignment presented by Jang Gyu Lee, Chan Gook Park and Heung Won Park, while it is not completely observable. In this model the east gyro drift rate is only weakly coupled to the velocities which would serve as external information for the purpose of alignment. So it is hard to give more attention to alignment accuracy and alignment speed during stationary self-alignment using the traditional initial alignment methods.

In this paper, a new self-alignment approach based on the measurement of IMU is proposed for SINS on a stationary base. The approach needn't to carry out SINS navigation calculation, thereby, it breaks away from the model which is not completely observable. Meanwhile, it takes full advantage of specific force and angular velocity information which is the sensed output of IMU as well as the characteristic of SINS stationary alignment. In order to make sure the high accuracy and speed of alignment, a new alignment model which is completely observable, is established for the approach. On the other hand, for the snake of self-alignment, IMU measurement is used as observations instead of velocities.

The main work of this paper is following: firstly, coarse alignment algorithm is presented. Secondly, a new fine alignment model for SINS stationary self-alignment is derived, and the observability of the model is analysed. Then, a modified Sage-Husa adaptive Kalman filter is introduced to estimate the misalignment angles. Finally, some computer simulation results illustrate the efficiency of the new approach and its advantages, such as higher alignment accuracy, shorter alignment time, more self-contained and less calculation.

Coarse alignment

Normally, SINS initial alignment process is divided into two phases, i.e., coarse alignment and fine alignment. The purpose of coarse alignment is to provide a fairly good initial condition for the fine alignment processing. For SINS stationary alignment, the carrier is fixed to the Earth. And some characteristics of stationary alignment are conclude as follow:

1) As a stationary carrier ($v_{en} \equiv 0$), the acceleration in navigation frame (the local-level east, north and up frame) equals zero, that is

$$\boldsymbol{a}^n = 0 \tag{1}$$

2) The angular velocity of the body frame with respect to the Earth-Fixed frame also equals zero, which can be written as

$$\omega_{eb} = 0 \tag{2}$$

According to the characteristics of SINS stationary alignment analyzed as above with the definition of specific force ($f=a-g$), we have

$$\boldsymbol{f}_{ib}^n = \boldsymbol{a}^n - \boldsymbol{g}^n = -\boldsymbol{g}^n = \begin{bmatrix} 0 \\ 0 \\ g \end{bmatrix} \tag{3}$$

and

$$\boldsymbol{\omega}_{ib}^n = \boldsymbol{\omega}_{ie}^n + \boldsymbol{\omega}_{eb}^n = \boldsymbol{\omega}_{ie}^n = \begin{bmatrix} 0 \\ \omega_{ie}\cos\varphi \\ \omega_{ie}\sin\varphi \end{bmatrix} \tag{4}$$

where g and ω_{ie} represent the magnitude of gravity and Earth rate, respectively, φ is the local geographical latitude.

For the SINS, the accelerometer and gyro output can be expressed respectively as

$$\boldsymbol{f}_{ib}^b = \boldsymbol{C}_n^b \boldsymbol{f}_{ib}^n$$

$$\boldsymbol{\omega}_{ib}^b = \boldsymbol{C}_n^b \boldsymbol{\omega}_{ib}^n$$

They also can be written as

$$\boldsymbol{f}_{ib}^n = \boldsymbol{C}_b^n \boldsymbol{f}_{ib}^b \tag{5}$$

$$\omega_{ib}^{n} = C_b^n \omega_{ib}^{b} \quad (6)$$

The vector cross-product based on f_{ib}^n and ω_{ib}^n is given by

$$
\begin{aligned}
f_{ib}^n \times \omega_{ib}^n &= [f_{ib}^n \times]\omega_{ib}^n \\
&= C_b^n [f_{ib}^b \times] C_n^b \omega_{ib}^n \\
&= C_b^n [f_{ib}^b \times] \omega_{ib}^b \\
&= C_b^n (f_{ib}^b \times \omega_{ib}^b)
\end{aligned} \quad (7)
$$

where $[f_{ib}^n \times]$ and $[f_{ib}^b \times]$ denote the skew-symmetric matrix of f_{ib}^n and f_{ib}^b respectively.

Then, combine (5), (6) and (7) into one matrix equation to obtain

$$\begin{bmatrix} f_{ib}^n & \omega_{ib}^n & f_{ib}^n \times \omega_{ib}^n \end{bmatrix} = C_b^n \begin{bmatrix} f_{ib}^b & \omega_{ib}^b & f_{ib}^b \times \omega_{ib}^b \end{bmatrix}$$

The transformation matrix can be expressed as

$$C_b^n = \begin{bmatrix} f_{ib}^n & \omega_{ib}^n & f_{ib}^n \times \omega_{ib}^n \end{bmatrix} \begin{bmatrix} f_{ib}^b & \omega_{ib}^b & f_{ib}^b \times \omega_{ib}^b \end{bmatrix}^{-1} \quad (8)$$

Equation (8) shows that the output of the accelerometers and gyros of a stationary SINS can be used to determine the attitude matrix directly.

Fine alignment

Coarse alignment is based on an idealization in which there are no accelerometer and gyro errors. But both accelerometers and gyros output data have errors in reality, especially the gyros may have large rate biases. So the attitude matrix given by coarse alignment may have some error. Now, using the notation $\hat{C}_b^n$ to denote the attitude matrix given by coarse alignment, and C_b^n represent the ideal attitude matrix, the relationship between $\hat{C}_b^n$ and C_b^n can be described as

$$\hat{C}_b^n = C_b^n + \delta C_b^n \quad (9)$$

δC_b^n is caused by errors in the orientation of the body frame with respect to the navigation frame. In terms of small misalignment angles, δC_b^n may be represented in the equivalent form of a skew-symmetric matrix

$$\delta C_b^n = [\phi \times] C_b^n \quad (10)$$

where ϕ denote the vector of misalignment angles, namely,

$$\phi = [\phi_E \; \phi_N \; \phi_U]^T$$

System equation

The mission of fine alignment is to obtain more accurate attitude matrix based on coarse alignment, that is, to estimate precise misalignment angles. In SINS stationary alignment, the misalignment angles remain constant, while no SINS navigation calculation is carried out. Then, the differential equations of misalignment angles can be written as

$$
\begin{cases}
\dot{\phi}_E = 0 \\
\dot{\phi}_N = 0 \\
\dot{\phi}_U = 0
\end{cases} \quad (11)
$$

Besides to determine misalignment angles in the alignment, we also need to estimate the biases of accelerometers and gyros which would be used to compensate the output of IMU during navigation. Here, the biases of accelerometers and gyros are considered as some noise processes which are consist of first order Gauss-Markov noise and Gaussian white noise. Thus, the IMU error model is written as

$$
\begin{cases}
\hat{f}_{ibx}^b = f_{ibx}^b + \delta f_{ibx}^b = f_{ibx}^b + \nabla_x + w_{ax} \\
\hat{f}_{iby}^b = f_{iby}^b + \delta f_{iby}^b = f_{iby}^b + \nabla_y + w_{ay} \\
\hat{f}_{ibz}^b = f_{ibz}^b + \delta f_{ibz}^b = f_{ibz}^b + \nabla_z + w_{az} \\
\hat{\omega}_{ibx}^b = \omega_{ibx}^b + \delta\omega_{ibx}^b = \omega_{ibx}^b + \varepsilon_x + w_{gx} \\
\hat{\omega}_{iby}^b = \omega_{iby}^b + \delta\omega_{iby}^b = \omega_{iby}^b + \varepsilon_y + w_{gy} \\
\hat{\omega}_{ibz}^b = \omega_{ibz}^b + \delta\omega_{ibz}^b = \omega_{ibz}^b + \varepsilon_z + w_{gz}
\end{cases} \quad (12)
$$

where

$$
\begin{cases}
\dot{\nabla}_x = -\beta_{\nabla_x} \nabla_x + w_{\nabla_x} \\
\dot{\nabla}_y = -\beta_{\nabla_y} \nabla_y + w_{\nabla_y} \\
\dot{\nabla}_z = -\beta_{\nabla_z} \nabla_z + w_{\nabla_z} \\
\dot{\varepsilon}_x = -\beta_{\varepsilon_x} \varepsilon_x + w_{\varepsilon_x} \\
\dot{\varepsilon}_y = -\beta_{\varepsilon_y} \varepsilon_y + w_{\varepsilon_y} \\
\dot{\varepsilon}_z = -\beta_{\varepsilon_z} \varepsilon_z + w_{\varepsilon_z}
\end{cases} \quad (13)
$$

Now, combine (11) and (13), system equation can be written as

$$\dot{X} = FX + W \quad (14)$$

where

$$X = \begin{bmatrix} \phi_E & \phi_N & \phi_U & \nabla_x & \nabla_y & \nabla_z & \varepsilon_x & \varepsilon_y & \varepsilon_z \end{bmatrix}^T$$

$$F = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -\beta_{\nabla_x} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -\beta_{\nabla_y} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -\beta_{\nabla_z} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -\beta_{\varepsilon_x} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\beta_{\varepsilon_y} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\beta_{\varepsilon_z}
\end{bmatrix}$$

$$W = \begin{bmatrix} 0 & 0 & 0 & w_{\nabla_x} & w_{\nabla_y} & w_{\nabla_z} & w_{\varepsilon_x} & w_{\varepsilon_y} & w_{\varepsilon_z} \end{bmatrix}^T$$

Measurement equation

Taking care of the error of accelerometers, (5) can be written as

$$
\begin{aligned}
f_{ib}^n &= C_b^n f_{ib}^b \\
&= (\hat{C}_b^n - \delta C_b^n)(\hat{f}_{ib}^b - \delta f_{ib}^b) \\
&= \hat{C}_b^n \hat{f}_{ib}^b - \delta C_b^n \hat{f}_{ib}^b - \hat{C}_b^n \delta f_{ib}^b + \delta C_b^n \delta f_{ib}^b
\end{aligned}
$$

Ignoring the high-order terms, we have

$$
\begin{aligned}
&= \hat{C}_b^n \hat{f}_{ib}^b - [\phi\times] C_b^n \hat{f}_{ib}^b - \hat{C}_b^n (\nabla + w_a) \\
&= \hat{C}_b^n \hat{f}_{ib}^b - [\phi\times] \hat{f}_{ib}^n - \hat{C}_b^n \nabla - \hat{C}_b^n w_a \\
&= \hat{C}_b^n \hat{f}_{ib}^b + [\hat{f}_{ib}^n \times]\phi - \hat{C}_b^n \nabla - \hat{C}_b^n w_a
\end{aligned}
$$

Define specific force measurement as

$$Z_f = f_{ib}^n - \hat{C}_b^n \hat{f}_{ib}^b = [\hat{f}_{ib}^n \times]\phi - \hat{C}_b^n \nabla - \hat{C}_b^n w_a \quad (15)$$

In the same way, Taking care of the error of gyro, (6) can be written as

$$
\begin{aligned}
\omega_{ib}^n &= C_b^n \omega_{ib}^b \\
&= (\hat{C}_b^n - \delta C_b^n)(\hat{\omega}_{ib}^b - \delta\omega_{ib}^b) \\
&= \hat{C}_b^n \hat{\omega}_{ib}^b - \delta C_b^n \hat{\omega}_{ib}^b - \hat{C}_b^n \delta\omega_{ib}^b + \delta C_b^n \delta\omega_{ib}^b
\end{aligned}
$$

Ignoring the high-order terms, we have

$$
\begin{aligned}
&= \hat{C}_b^n \hat{\omega}_{ib}^b - [\phi\times] C_b^n \hat{\omega}_{ib}^b - \hat{C}_b^n (\varepsilon + w_g) \\
&= \hat{C}_b^n \hat{\omega}_{ib}^b - [\phi\times] \hat{\omega}_{ib}^n - \hat{C}_b^n \varepsilon - \hat{C}_b^n w_g \\
&= \hat{C}_b^n \hat{\omega}_{ib}^b + [\hat{\omega}_{ib}^n \times]\phi - \hat{C}_b^n \varepsilon - \hat{C}_b^n w_g
\end{aligned}
$$

Define angular velocity measurement as

$$Z_\omega = \omega_{ib}^n - \hat{C}_b^n \hat{\omega}_{ib}^b = [\hat{\omega}_{ib}^n \times]\phi - \hat{C}_b^n \varepsilon - \hat{C}_b^n w_g \quad (16)$$

Then, combine (15) and (16), measurement equation can be written as

$$Z = HX + V \qquad (17)$$

where

$$Z = \begin{bmatrix} Z_f \\ Z_\omega \end{bmatrix} = \begin{bmatrix} f_{ib}^n - \hat{C}_b^n \hat{f}_{ib}^b \\ \omega_{ib}^n - \hat{C}_b^n \hat{\omega}_{ib}^b \end{bmatrix}$$

$$H = \begin{bmatrix} [\hat{f}_{ib}^n \times] & -\hat{C}_b^n & O_{3\times3} \\ [\hat{\omega}_{ib}^n \times] & O_{3\times3} & -\hat{C}_b^n \end{bmatrix}$$

$$V = \begin{bmatrix} w_a \\ w_g \end{bmatrix}$$

Observability analysis

The accuracy and speed of alignment is decided by the performance of filter, which is decided by the observability of model. So the observability analysis of model must be performed before filter can commence. The SINS stationary alignment model established in this paper, is a linear time-invariant system whose observability can be obtained by the analysis of the observable matrix. The rank of the observable matrix is

$$rank(Q) = rank(\begin{bmatrix} H \\ HF \\ HF^2 \\ \cdots \\ HF^{n-1} \end{bmatrix}) = 9$$

It shows that the model is complete observable. And the filter is capable of estimating the state with good performance, therefore, the model will lead to a high accuracy and speed of alignment.

Modified Sage-Husa adaptive Kalman filter

Sage-Husa adaptive Kalman filter algorithm proposed by Sage A P and Husa G W, is a filter algorithm which can estimate system noise and measurement noise online in real-time. However, the algorithm could run well under the unknown prior statistical characteristics circumstance. There are some problems with the algorithm, such as, 1) stability and astringency of measurement noise is poor, which affect stability of state estimation and filter result directly, 2) system noise and measurement noise can't be obtained accuracy at the same time, 3) The minus operation would make the matrix of system noisy estimation and the matrix of measure noisy estimation lose half positive or positive, which will make the filter diverge.

In order to solve the problems analyzed as above, a modified Sage-Husa adaptive Kalman filter algorithm is proposed as follow

$$\hat{X}_k = \hat{X}_{k|k-1} + K_k \varepsilon_k \qquad (18)$$

$$\varepsilon_k = Z_k - H_k X_{k|k-1} \qquad (19)$$

$$\hat{X}_{k|k-1} = \Phi_{k,k-1} \hat{X}_{k-1} + \hat{q}_{k-1} \qquad (20)$$

$$K_k = P_{k|k-1} H_k^{\mathrm{T}} [H_k P_{k|k-1} H_k^T + R_{k-1}]^{-1} \qquad (21)$$

$$P_{k|k-1} = \Phi_{k,k-1} P_{k-1} \Phi_{k,k-1}^{\mathrm{T}} + \hat{Q}_{k-1} \qquad (22)$$

$$P_k = [I - K_k H_k] P_{k|k-1} \qquad (23)$$

$$\hat{q}_k = \frac{1}{k}[(k-1)\hat{q}_{k-1} + \hat{X}_k - \Phi_{k,k-1}\hat{X}_{k-1}] \qquad (24)$$

$$\hat{Q}_k = \frac{1}{k}[(k-1)\hat{Q}_{k-1} + K_k \varepsilon_k \varepsilon_k^{\mathrm{T}} K_k^{\mathrm{T}}] \qquad (25)$$

Simulation

During the simulation, parameters of a medium accuracy IMU are used. Its details are shown as following.

Initial misalignment angles	1 °
Accelerometers white noise biases	100 µg
Accelerometers first order markov biases	100 µg
Accelerometers first order markov time constant	3600 s
Gyros white noise drift	0.01 ° h-1
Gyros first order markov drift	0.01 ° h-1
Gyros first order markov time constant	3600 s

Simulation results are given in figures 1-6, which figures 1-3 are the errors of attitude angle and figures 4-6 show the estimation errors of gyro drift rate.

Figures 1-6 show that the filter works well. After less than 5 s, it have already converged rapidly. According to the computer simulation results, the errors of the two leveling attitude angles are about 5 '', and the error of the azimuth angle is about 1.5 '. Computer simulation results also verify that the optimal time of the three misalignment angles is less than 5 s. Figures 4-6 show that three gyros drift rate are estimated accurately. While the traditional initial alignment have the alignment accuracy of 10 '' for leveling attitude angles and 2-5 ' for azimuth angle, with the alignment time of 20-50 s.

Conclusion

Because of the poor observability of the system, it is hard to give attention to the accuracy and speed of alignment by the traditional initial alignment technology. In order to solve this problem, through analyzing the characteristic of the SINS stationary alignment seriously, a bran-new SINS stationary alignment approach is proposed by means of establishing new system model and measurement model. The new approach could complete the SINS stationary alignment process through the outputs of IMU without any external information.

According to the observability analysis,

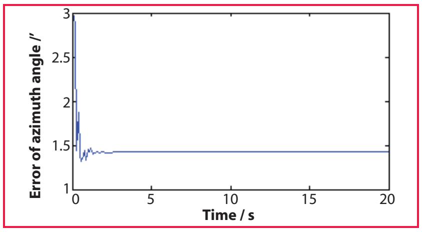

Figure 1 Error of azimuth angle

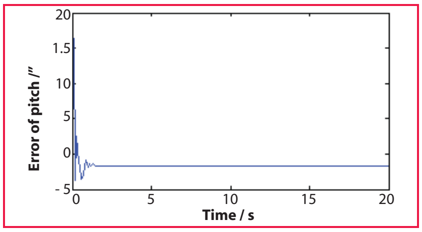

Figure 2 Error of pitch

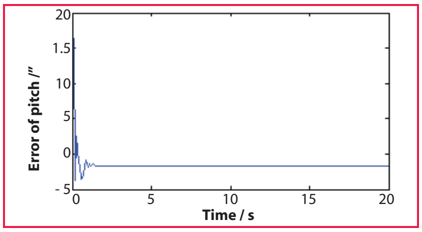

Figure 3 Error of roll

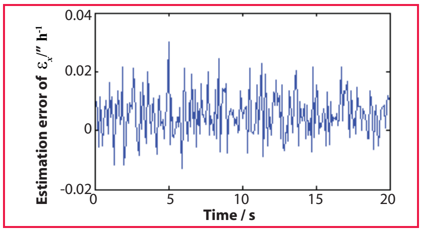

Figure 4 Estimation error of ε_x

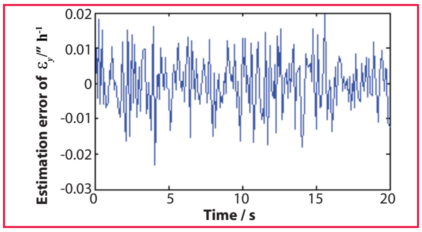

Figure 5 Estimation error of ε_y

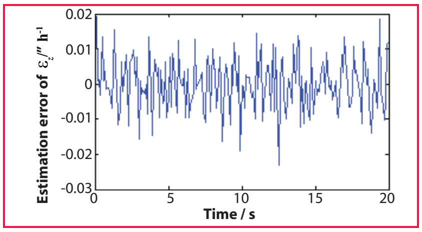

Figure 6 Estimation error of ε_z

the alignment model established in this paper, is complete observable, which brings the excellent performance of the filter as well as the high accuracy and speed of the alignment. Compared with the traditional initial alignment technology, the new approach have such advantages as follow: it could estimate all states include east gyro drift rate and azimuth misalignment angle accurately in short time; higher alignment accurate; shorter alignment time; more self-contained and less calculation. Therefore, the new approach is a preferable choice for SINS stationary self-alignment.

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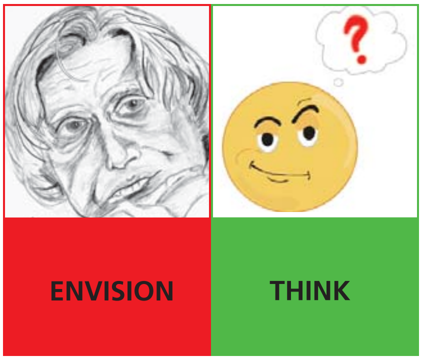

The datum debate continues

Readers may recall the vision and mission outlined by the Dr APJ Abdul Kalam, the President of India (Coordinates, December 2006). Alongside we printed an open letter from Dr Muneendra Kumar addressed to the President where he emphasized the need to modernize the datum. Some experts respond:

We need Everest 2007 soon

Prof M N Kulkarni,
IIT Bombay

Do you think that we are using outdated datum?

In India, for topographical mapping, we are using an old Geodetic Datum (reference ellipsoid on which the coordinates: Latitude and Longitude are projected, and mapping is carried out), called Everest 1880, defined by the work of Col. George Everest (one of the greatest Geodesists, for whom the highest peak in the world is named). It is a local datum, best-fitting for India (as in 1880), but not fitting the Earth as a whole in the best possible manner.

Many countries in the world have been using their own local datums, and most have already redefined their datum, or have started using the global datum (fitting the entire Earth): WGS84, defined by the Defense Mapping Agency (DMA), USA, which the GPS uses. Thus, all our Indian topogrphical maps (topo sheets) still use Everest1880 ellipsoid, and GPS gives coordinates on WGS84. If we use GPS and plot the coordinates observed on a toposheet, we will be mixing apples and oranges: the positions will differ by as much as 300 to 500 metres! Hence, the solutions are:

(i) Use WGS84 as map datum, and GPS or- (ii) Use the conversion factors (called transformation parameters) to convert GPS coordinates to Everest, and use with Indian topo sheets.

It is true that we are using on old datum, but it is being re-defined under a project launched by Survey of India (SoI) in the late 80s. I was in-charge of this project for 6 years (till I joined IIT Bombay). Similar project completed by USA for their datum: re-defined as North American Datum 1983 (NAD83) from NAD1927, used a very large manpower and huge funds, and took over 10 years. In SoI, we had just 4-5 persons, with a meagre budget for such project. This is an important project, and needs urgent attention of Government of India. We need Everest2007 soon!!

However, according to the recent map policy of Government of India, now being implemented by the SoI, only the security classified Defence maps will use the old datum: Everest 1880, and all open maps, for developmental projects, general public use etc. will use WGS84 as datum. Thus, general public can use GPS with these maps. That should solve the major problem. Modernization, developmental projects, etc. will not be affected. The problem is in making these new WGS84 maps available to the public early, which SOI should take on priority. Till that time, the problems will remain. Another problem is that heights/contours on these new maps are not being made available easily to public, due to Defence restrictions. That is a setback, and needs to be removed: heights/ contours are most essential in a map.

If yes, then why can't we update it?

As mentioned above, the India Geodetic Datum is being re-defined. But the project has been relegated to the back-burner. It should be given top priority, required funding and manpower, and completed immediately. Changing all the maps to a new datum is a huge task, requiring huge resources, funds, manpower, etc. But it is important, and must be done on priority.

Should we use WGS 84 or not?

Most countries in the world are using WGS84 as the datum for their mapping. It is a datum which is here to stay, possibly for a few decades, for mapping and navigational purposes. For scientific applications like eathquake research, plate motions studies etc., scientific datums called International Terrestrial Reference Frames (ITRF) are defined by the International Earth Rotation Service (IERS) every year (ITRF2005, etc.). But for mapping, navigation, developmental projects, infrastructure development, and most common applications, WGS84 is good enough.

The Universal Transverse Mercator Map Projection and Grid System (UTM), used most widely all over the world, is also the most scientific, convenient and digital mapping-compatible system, and should be used for these maps.

Dr Kumar says solutions are available, Do you agree?

Indian geodesists have the know-how and expertise to carry out these tasks. Of course, all help from expert agencies like National Geodetic Survey, USA; DMA, USA, and expert persons like Dr Muneendra Kumar is welcome and should be taken. Unfortunately, many of our Government departments like SoI do not make use of the expertise available outside their own Department, like experts in other scientific and academic organisations and Institutes, retired Geodesists, etc. Their contribution and advice would be of great help in putting these highly scientific tasks on the right track and in expediting them. Probably an eminent and young, dynamic Geodesist as Head of SoI would be able to provide the leadership and guidance required for these important national tasks!

Not advisable to stick to weak datum

Lt Gen Surindar P Mehta (Retired), Former Surveyor General of India

Questions have been raised at various quarters whether the Vision invoked by the President can be fulfilled by using 19th century Datum.

Before I comment on this, let us review briefly the broad classification of Mapping /Cartographic effort required for various applications.

- Cartography for Global level planning and execution. This calls for most accurate techniques to depict the shape and size of the earth. Requires most accurate absolute positioning of points on globe to ascertain correct distance, directions, areas, volumes, essential for various global activities such as Global Warfare, Continental Drift, etc. Also involves very precise measurements of International boundaries. There is the requirement of most precise control network based on well defined Datum.
- Cartography for Macro level planning and execution. Requires depiction of all major topographical details (both physical and manmade) relatively correct to enable macro level study and planning of land related activities. Topographical maps on scale 1:25000 to 1:250000 have been used. Relative accuracy is important and distance, area and volume can be computed within limited accuracy, generally acceptable for macro level planning. Any suitable cartographic projection with any reasonable datum can serve the purpose.
- Cartography for Micro level planning and execution. This requires all terrain data accurate in size and shape in relative correct position so as to get true distance, area and volumes for micro level planning and execution of land related projects. These are large scale maps of the small area of interest. Some of the Engineering projects (such as Irrigation) , require study on map scale 1:5000 to 1:10000 and further detailed planning, design and execution on larger scale (1:1000 or even larger). Relative accuracy of positioning of details is the prime requirement and absolute positioning and well defined datum is not mendatory.

Let us now examine major inputs required for various requirements projected by the President.

Providing Urban Amenities in Rural Areas

Requires mapping on large scale (1:10000 or larger 1: 2000) for 7000 PURAS (6 lakhs villages / 2 lakhs panchayats) in 2 years time. Requires huge survey and mapping effort. It is advisable to collect terrain data based on the existing control network , rather than waiting for any new Datum definition.

Jawahar Lal Nehru National Urban Renewal Mission

Requires preparation of Base maps on large scale (1:2000 or 1:4000) with contours at 1m interval for 63 large cities for proper planning and layout of road network and utilities. Considering time limitations, terrain data may be acquired based on existing control network. As stressed by the President, all city administration agencies should use this base data for their applications, to ensure uniformity and avoiding wasteful duplicate effort. Survey of India should, however, examine the security aspect of this base map with heights 1m or less for free public use.

Disaster management

Existing topographical maps duly updated using aerial photographs and high resolution imageries will serve the purpose. Additional details, as required, can also be incorporated on the same maps.

Mapping thermal potential

Existing topographical maps duly updated can serve base maps for superimposition of thematic information of thermal potential to be collected by specialized agencies.

Cartography enabled technology

It is heartening to note that India has its own CARTOSAT for high resolution terrain data. This will generally meet the requirements of topographical maps and DEM of 8m accuracy. This will be useful for Feasibility studies, but will need additional survey effort for detailed designs and layout of infrastructures and utilities.

Mission for cartographers

President has asked for creating a network for all organizations, which should essentially be carried out by the government (DST).Mapping of large scale maps for PURA and JNNURM in about 2 years time is a real challenge for Survey of India. Uploading of digital data on the web site will be a dream come true, considering the hurdles to be encountered from various agencies.

Special resources will have to be catered for updating existing base maps required for Disaster Management and Wasteland Mapping.President has expressed the need for training and building a human resource team, which can face the challenges of the 21st century. This involves imparting of indepth knowledge of geodetic science and allied disciplines like digital cartography, GIS. In addition to updating courses in STI, Hyderabad, there is the requirement of establishment of more such Institutions in India as well as continuous interaction and collaboration with prestigious institutions of developed countries.In addition , major users, engineers, geographers and scientists involved in geoscience need to be educated in the basics of these fundamental disciplines so that they can utilize terrain data usefully.

Need for review of datum

Any useful mapping has to be based on accurate control network. India has vast network of ground control points based on datum weak in definition but good enough for relative positioning of vast amount of terrain data required for development projects in a short time frame. India has a vision of transforming itself into a developed nation before 2020 and has to face the cartographic challenges of 21st century. Most precise well defined coordinate system is a requirement for global warfare as well as for carrying out research in disciplines like seismic studies, continental drift etc. I am sure that SoI will take appropriate steps and adopt most suitable well defined datum to meet these challenges. It is also not advisable to have two different datum, projections and grid systems in 2 series of maps. These will create operational problems, besides being costly proposition. Moreover, it is not advisable to stick to weak datum (Everest) for Defense Series Maps when we want to operate on global platform.

Redefinition of Indian datum is necessary

N K Agrawal, Former Director, Survey Training Institute, Survey of India

Firstly let us call the datum as Indian datum based on Everest Spheroid 1830. Redefinition of Indian datum is necessary and should be done at the earliest. I understand that Survey of India has taken it up, but its status is not known. Status should be put on the SoI website. A geocentric reference datum is necessary for defence applications and research including study of plate movements, crustal movements, subsidence, rise in sea level etc. A new vertical datum is also necessary. I understand that SoI has initiated action to define a new vertical datum.

Why say, GPS accuracy? We should define accuracy in parts per million or simply zero, 1st, 2nd, 3rd, or 4th order accuracy. GPS is capable of giving zero order (better than 3 to 4 parts per million) as well as 4th order (less than 1 in 5000) accuracy. These accuracies are achievable with other instruments and techniques as well. Further our maps are designed very well and with adequate accuracy and need not be linked to GPS accuracy. Only the map projection for topographical maps, polyconic projection that is being used in a way, assuming no distortion and curves is not correct and creates difficulties in compilation and digitization.

Now let us see as to what the honourable President has mentioned in his VISION. These are as follows: -

1. PURA,
2. JNN Urban Renewal Mission,
3. Disaster management,
4. Flood and Water management,
5. Flood control through layered wells,
6. Six missions for cartographers.

Most of the above can be achieved even with the present Indian datum and vertical datum for MSL heights.

Some problems may however arise in respect of defence applications, research and high-end civil applications like crustal movements, interlinking of rivers etc. This means that we have got to change over to a new geocentric reference datum, and a new vertical datum anyway then why not do it now and produce all maps in the new datum. Most important for President's vision are Redefinition of Indian Horizontal datum as well as vertical datum, availability of horizontal and vertical control points of at least 3rd order accuracy at every 2 km, adoption of LCC or TM projection for maps by breaking India into a number of convenient zones for all types of mapping. All development mapping should become a state subject with a grid of their own on similar lines to SPCS (State Plane Coordinate System) for various states in USA. Main hindrance to Presidents vision comes from Restriction policy, confused map policy, lack of transparency, clear thinking, funds, and trained manpower.

Galileo update

Galileo – the European Programme for Global Navigation Services for civil purposes is an initiative led by European Union. We provide regular updates to our readers on the Galileo programme.

ESA Chief says Galileo test problems are being fixed

European space chief Jean-Jacques Dordain said that problems encountered by a test satellite for the Galileo sat-nav system were being addressed, although he gave no date for its launch. Galileo plans to have around 30 satellites and be running commercially from 2010. The European Space Agency (ESA) has contracts to launch and test two experimental satellites to confirm Galileo's technology, and also to provide the first four of the 30 satellites. The first satellite, GIOVE-A, successfully launched in December 2005, but its companion, GIOVE-B -- initially scheduled to be hoisted aloft in early 2006 -- has twice been postponed. Dordain, who is ESA's director general, said the delay was "due to a technical problem with a component which failed during tests, but we also encountered organisational problems." "As soon as the problems emerged, we set up three investigative groups, working in parallel. When they reported back, we took technical and organisational action that should enable us to launch GIOVE-B this year." *www.spacedaily.com*

Galileo project 'hindering' phone sat-nav rollout

Galileo is becoming a barrier to the integration of satellite navigation into European handsets, a mobile operator claimed. According to Ian Curran, head of telematics and machine-to-machine communications at O2, operators and manufacturers remain uncertain over the deployment schedule for Galileo and the likely quality of its signal. Although the mobile industry wants to put some form of GNSS functionality into phones, some companies within it are hesitant about which system to use. The only GNSS currently in action is GPS. However, Galileo — which should be fully operational by the end of 2008 — will supposedly provide greater accuracy, leaving some in the industry wondering whether they should invest in compatibility with GPS, Galileo or both (a path that appears to have been taken by the UK-based chipset manufacturer CSR). *http://news.zdnet.co.uk*

New web site on GIOVE mission

One year ago, GIOVE-A began transmitting Galileo navigation signals. This satellite is the first flight element in ESA's in-orbit validation programme for Galileo. This signal transmission has secured the use of the frequencies allocated to the Galileo system by the International Telecommunication Unit (ITU), achieving the primary mission for which the satellite was constructed. The receivers that have been developed for Galileo were able to receive the first signals at ESA sites at Redu (Belgium) and Noordwijk (Netherlands), at the Chilbolton Observatory (UK) and at the Guildford (UK) mission control centre of Surrey Satellite Technology Ltd, the prime contractor for GIOVE-A. Information on the GIOVE mission is now accessible at www.giove.esa.int. This new web site provides general information to the public and measurement data and core products to registered external users who are collaborating with ESA on the mission experiments. *www.innovations-report.de*

Online: GPS-GAP

GPS-GAP has been designed as a cost effective approach to education that takes advantage of the internet

Dr Alfred Leick

GPS has demonstrated a stellar performance ever since its inception. In fact the satellites typically operate beyond their expected lifetime which potentially creates obstacles to the timely modernization of the system. GPS-GAP (GPS, Geodesy and Application Program) is an online educational initiative by the University of Maine that offers in-depth knowledge about this fantastic system and its uses.

My enthusiasm for GPS began when testing the experimental Macrometer receiver during the summer of 1982 at M.I.T. over a 30 km baseline from Woburn, MA, to Mount Watchusett. The satellite visibility ranged from about 6 p.m. to midnight in New England. Many of the sunset watchers at the summit were puzzled by my activities and impressed by the huge piece of equipment in the back of my station wagon, the abundance of cables, and the strange looking antenna (so they thought). Their puzzlement about what I was up to was reflected in some of their comments, such as "Is this thing taking off?", or "Are you on our side?" Of course, there was plenty of time until midnight to be entertained by Fourier transforms and such on the computer screen, and to ponder the unlimited potential of GPS. Whatever has evolved since those days in terms of civil uses of GPS needs no further explanation.

Those long evening hours on top of Mount Watchusett allowed not only double-checking the fantastic repeatability of the observed baseline vector night after night, but also to marvel at the science behind all of that. There was the prospect that GPS could revolutionize my field of specialization, i.e. geodesy and that we could gain a better understanding of the variations of the atmosphere. There certainly was curiosity as to what signals the satellites actually transmitted. I was told that it was so weak that it was below the background noise. And yes, why was this antenna so large that onlookers thought it might take off and why was the computer crunching all night? What precisely were those carrier phases we used to compute the baseline? How did observations from a global network of tracking stations arrive at the control center? The latter certainly caught my attention since I was using the forerunner of the internet, the BITNET, to supervise a graduate student in Maine, thus gathering my first experience with distance education. Of course, during the day we talked about gravity, solar radiation pressure, relativity, multipath, ambiguity fixing, modeling, and so on.

My amazement with the science underlying GPS satellite surveying made me rush to establish a graduate course in GPS that Fall at the University of Maine. The urge to tell the GPS story propagated into three editions of my book GPS Satellite Surveying and into the series of GPS-GAP internet courses. As a faculty member I have been wondering for a long time when should we stop recommending astronomy to our students to fulfill science requirements and alternatively recommend GPS, which is "much closer to home" and has such an abundance of science to offer. Of course we no longer need the station wagon and midnight observations.

GPS-GAP has been designed as a cost effective approach to education that takes advantage of the internet. The courses are offered asynchronously, the class size is one, i.e. there is individualized instruction, and a course can start any. The time constraints of the traditional semester calendar do not apply.

The courses can be taken in the work place, at times convenient for the student, and at a pace that fits the needs of the individual. A dedicated server runs live computations with relevant data and actual GPS observations. To avoid incompatibilities in programming skills, all computations are programmed with Mathcad, which can be learned "on the fly" because of its intuitive graphical programming interface. Students are not required to buy any software. An internet browser is all that is necessary to take the courses. Computer graded exams are available for assessment.

Details about GPS-GAP are found at www.gnss.umaine.edu. The material covered is closely tied to the textbook GPS Satellite Surveying (3rd edition). The quiz questions play an important and integral part in the iterative learning strategy. The courses have been designed as 1-credit hour units, allowing the students to navigate the sequence of the courses and taking advantage of their prior knowledge of the subject.

Interested students might consult the textbook to get an even better feeling about the depth of coverage. The material is presented with sufficient depth as needed for understanding all geospatial positioning accuracy levels, ranging from 100 meter to millimeter, in either real-time or post process. Such topics as ambiguity fixing, conventional and network RTK, VRS (Virtual Reference Station) networks, geometry-free solutions and precise point positioning of course are included.

Dr Alfred Leick, Professor at the University of Maine, Orono, Maine, is author of the book GPS Satellite Surveying, published by J Wiley. He is also Editor-In-Chief of GPS Solutions. **leick@maine.edu**

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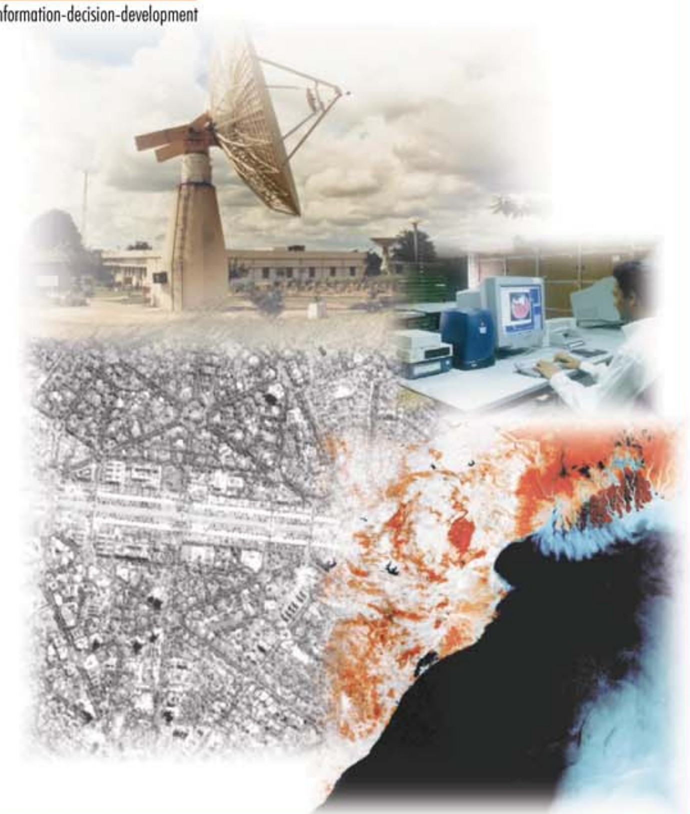

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Fax: + 91-40-23878158/23878664

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URL: www.nrsa.gov.in

Leica FCMS Flight & Sensor Control Management System

Sweden-based Leica Geosystems' Flight & Sensor Control Management System (FCMS), assists pilots and sensor operators to efficiently control GPS-based survey flights. It performs all tasks, such as flight guidance, sensor recording and sensor monitoring, on a single man-machine interface, providing automated operation and minimized user interaction.

Leica Geosystems also introduces the Rugby 50 and Rugby 55. With the Leica Rugby 50 and 55 are two new lasers that are designed for different applications: The Rugby 50 is dedicated to general construction contractors, being a tough, affordable laser with a single button. Whereas the Leica Rugby 55 is designed for the interior contractor – a versatile laser, perfect for almost any leveling and alignment job.

In addition, Leica Geosystems has also announced a new enterprise software licensing program called Leica EnterpriseElite. Qualified companies benefit from simplified software license management tools, flexibility to immediately react to changing project demands, significant software cost savings, and the ability to efficiently standardize an entire global organization. *www.leica-geosystems.com*

GLONASS launch provides more coverage to Topcon customers

For years Topcon's GPS+ has been the only system that allowed its users the option to access the GPS and GLONASS satellite constellations. Now, with its new line of G3 receivers, TPS customers will also be able to receive signals from the Galileo system. *www.topconpositioning.com*

Symmetricom announces IEEE 1588 Grandmaster Clock

Symmetricom, Inc., announced its XLi IEEE 1588 Grandmaster Clock with GPS reference for IEEE 1588 protocol test and measurement applications. This protocol enables very accurate synchronization over Ethernet LANs and offers users the ability to synchronize clocks to better than one hundred nanoseconds accuracy with only a network connection. The XLi IEEE 1588 Grandmaster provides the precise time and is also equipped to physically measure how well that time is transferred through the network with precision down to five nanoseconds resolution. *www.symmetricom.com*

Globalsat GH-615 GPS watch

Globalsat, Taiwan announced release of GH-615 wristwatch. It houses a SiRF Star III GPS antenna, supports WAAS/ EGNOS, and offers up tracking, positioning, and time alert functions. It can also be connected via USB to double as a GPS receiver for laptops and other mapping applications, and it's pre-programmed to record the user's route by marking and saving tracking points. *http://tabletpcs.engadget.com*

Boeing gets USD 50 million GPS contract

Boeing has completed a critical US Air Force review of its GPS Space Segment III program and has been awarded a USD 50 million contract for additional system design activities. The Delta System Requirements Review, completed in November, featured an incremental capability insertion approach designed to ensure low development and delivery risks. The review is part of a USD 10 million follow-on order to the Phase A Concept Development Contract awarded in 2004. The U.S. Air Force is expected to award the multi-billion dollar GPS III contract in 2007. *www.boeing.com*

Airports Authority of India selects ESRI Enterprise GIS technology

The Airports Authority of India (AAI), has awarded the NOCAS (No Objection Certificate Application System) project to NIIT , parent company of NIIT-GIS Ltd.. The project automates the prioritization and processing of NOC applications based on criteria established by AAI, which will greatly streamline the approval process. A NOC for height clearance issued by AAI is required for construction projects, that fall within 20 km of an airport. *www.esri.com*

EILABS announces private label Program for vehicle tracking

It seeks service oriented partners interested in providing vehicle tracking solutions to their customers which will provide complete technology solution including hardware, software and tracking portal with maps. The portal and devices will be co-branded with partners. *www.eilabsindia.com*

Contex announces JETimageNET software upgrade

Contex, announces the release of JETimageNET version 6.3.2 software upgrade, which now offers support for an even larger number of large format professional printers. Contex is the "No.1 Market Share Brand in year 2006" and "Customers' First Choice for Wide Format Scanners in the year 2007" awarded by the Association of Chinese Computer Users in January 2007. *http://support.contex.com/software/jetimagenet/*

u-blox to support offline instant positioning

u-blox AG, announced that it has extended its AssistNow A-GPS servicewhich which would provide A-GPS assistance data that enables instant positioning over extended time periods without the need for mobile connectivity. *www.u-blox.com*

Tough New Spectra Precision Grade Lasers

Trimble has announced the new Spectra Precision® GL412 and GL422 Grade Lasers. It can perform three types of jobs for the construction contractors—level, grade and provide vertical alignment with plumb. The GL412 and GL422 Grade Lasers send a continuous, self-leveled 360-degree laser reference over an entire work area, and feature a wide grade range of -10 to +15 percent, so they can be used for a range of slope applications.

Trimble has also introduced Trimble VX Spatial Station, an advanced positioning system that combines optical, 3D scanning and video capabilities – Trimble VISION technology – to measure objects in 3D to produce 2D and 3D data sets for spatial imaging projects. *www.trimble.com.*

Blue Marble updates GeoCalc software

Blue Marble Geographics announces another update to their GeoCalc software development kit. This fully object-oriented, cross platform coordinate conversion library is now completely interoperable with most major GIS software tools available today. *www.bluemarblegeo.com*

Bank of America signs on for GPS Navigation Service

Bank of America is teaming up with Tele Atlas to make branch locations part of GPS and in-car navigation system networks so as to ensure travelers can find one of its branches as needed. *www.localtechwire.com*

Raytheon gets USD 6.8 million US Navy deal

The US Navy has awarded a USD 6.8 million contract to Raytheon Co. It will develop a landing system to guide aircraft safely onto ships using global positioning system technology. *http://news.moneycentral.msn.com*

ProjectWise Navigator unveiled by Bentley

Bentley Systems has unveiled ProjectWise Navigator. It complements the ProjectWise system of collaboration servers, which is already used by nine of the top ten ENR 500 design firms to connect people and information across their distributed enterprises. *www.bentley.com*

Navman announces Smart GPS Sensor

Navman, announced a tethered GPS receiver and antenna device, the Smart GPS Sensor with SiRFStar III technology. *www.prnewswire.com*

ASUS S102 portable navigation device

Taiwanese firm ASUS incorporates high-sensitivity antenna technology in its latest launch S102 PND. It utilizes advanced natural voice technology as well, enabling clearly pronounced turn-by-turn instructions. *www.asus.com*

NovAtel Inc. GPS Engines OnBoard Port of China Container

Beijing BDSTAR Navigation Co. Ltd., dealer of NovAtel Inc. in China, completed deployment of NovAtel GPS-based systems for the Shanghai Yangshan port Container Terminals (SYCT), one of the largest cargo ports in the world. The GPS engines will power a system used for positioning and tracking all container-handling equipment in Yangshan Port Phase I and Phase II terminals, including quayside cranes, rubber-tired gantry cranes, forklifts, reachstackers and trailers. NovAtel has supplied about 500 GPS receivers to BDSTAR

New Version Bathymetric Data Management Software

CARIS releases Bathy DataBASE 2.0 for the creation and management of bathymetric surfaces. It was developed to allow hydrographers to overcome obstacles of large bathymetric data sets and data sources. The software allows users to validate, prepare and compile bathymetric data from multiple formats and sources to create products.

Toposys Airborne laser sensor

TopoSys introduces airborne laser sensor system - “5 Harrier 56/G3”. It allows scanning with world-leading 200,000 laser pulses per second and provides highest level of details for applications such as corridor mapping.

The present system is an improved sensor than the previous Harrier 56 that was introduced in October 2005. Currently it is the highest pulse rate of an Airborne Laserscanning sensor system.

BCCL Times Group Invests in SatNav

The Times Group, whose parent company Benett and Coleman is India’s most diverse and largest media house, has invested 7 Crores in SatNav for a minority stake. *www.satnav.com*

PCI Geomatics celebrates the unveiling of GeoCapacity

PCI Geomatics®, had a series of events in India in January, to showcase the success of the first phase of the Agricultural GeoCapacity Network (AGCN) project. In partnership with the Punjab Remote Sensing Center, PAU, Info-Electronic Systems (Montreal and New Delhi) and CIDA Inc, the AGCN phase I project provides a proof of concept that illustrates how information on crop yields and trend analysis can be automatically generated and delivered to scientists, government officials and the general public via a simple web browser. *www.pcigeomatics.com*

Russia, India sign agreements on GLONASS

Russia and India has signed two cooperation agreements on GLONASS, which will be used by Moscow's long-time partner in the military-technical sector. The agreements were signed by the head of Russia's Federal Space Agency, Anatoly Perminov, and Madhavan Nair, chairman of the Indian Space Research Organization (ISRO).

Perminov earlier said Russia and India plan to jointly use GLONASS. Russian Defense Minister Sergei Ivanov said that Moscow and New Delhi had agreed to launch GLONASS-M satellites with the help of Indian booster rockets, and to create new-generation navigation satellites. The Russian Ministry of Defense has already lifted all restrictions on obtaining and using the geospatial information provided by the GLONASS. *http://en.rian.ru*

Tribes use GPS and Google Earth in conservation effort

Mark Plotkin, head of the Amazon Conservation Team and his colleagues are teaching Amazon Indians to use handheld GPS computers and Googlemaps. It is being used to plot water sources, areas of illegal logging, sacred areas, hunting spots, religious sanctuaries, medicinal plants and much more. The result is detailed maps of areas that are both very vulnerable to exploitation (e.g. illegal logging) and very difficult to patrol and protect. *www.newscientist.com*

World GPS market forecast

Allbizreport.com announces the World GPS Market Forecast (2006-2008) report reviews the recent market status, developments and capabilities of GPS. The key findings are

- The worldwide GPS market will reach a value of more than US$ 30 Billion approximately by 2008.
- The people tracking and handset market segments under GPS will have the largest growth rate, of approximately 9%, by 2008.
- Use of digital signaling and media broadcasts has increased the demand for the use of network applications fitted with GPS tools, thereby paving the way for cheaper and more reliable GPS devices.
- The key opportunity lies in the field of RFID.
- However, cost of deployment would be a major deciding factor. *www.allbizreport.com*

GPS and the Internet improves International time coordination

International time coordination is improving throughout the Americas by using a system that relies on GPS satellites and the Internet. The time and frequency network of the Sistema Interamericano de Metrologia (SIM), or Inter-American Metrology System, began operation in 2005 and includes national metrology institutes in member nations of the Organization of American States (OAS). The SIM network currently compares time and frequency measurements made in Brazil, Canada, Mexico, Panama and the USA. Costa Rica and Columbia are expected join the network soon, and additional OAS members have expressed interest. *www.ccnmag.com*

US considers shutting down LORAN system

The Transportation Department (DOT) of USA wants comments on whether to shut down the ground-based Long-Range Navigation (LORAN) system operated by the Coast Guard or to develop a fully deployed enhanced LORAN (eLORAN) system that could serve as a GPS backup. It is also working with the Homeland Security Department, which includes the Coast Guard, to determine whether investments made so far now merit consideration of eLORAN as a complementary electronic system to GPS. The Coast Guard has spent USD 160 million on LORAN modernization since 1997. *www.fcw.com*

Chronos, NPL and Bath University form Saturn Consortium

Chronos Technology, the National Physical Laboratory (NPL) and Bath University announce the formation of the Saturn Consortium The consortium proposes to assess the susceptibility of GNSS applications to external interference and multi-path problems. It aims to develop cost effective techniques to assess local availability of GNSS transmissions, and to define new standards for Galileo integrity and availability at the point of use. *louise.davies@chronos.co.uk*

In India

- A team of cartography experts has installed a GPS in Dharmapuri to receive updated data on topographical conditions from satellites. As part of the initiatives of the Survey of India to update the topographical data of the country by installing 300 GPS, teams of cartography experts have camped at 300 points in 30 States. *www.newindpress.com*

- A project developed jointly by the Indian Institute of Technology-Kanpur, and the Research Designs and Standards Organisation (RDSO), Lucknow, a tracking device called Satellite Imaging for Rail Navigation (SIMRAN) will be installed on 40 trains and a similar number of stations on the Kanpur-Allahabad route in the first phase. *http://cities.expressindia.com*

- People travelling by Bangalore Metropolitan Transport Corporation buses will get real-time information about arrival of buses at stops enroute by January-end. The corporation has placed orders for supply and operation of electronic display boards for passenger information system with a Bangalore-based information technology firm on a Build, Own, Operate and Transfer basis. The supply would begin by month-end *www.hindu.com*

GloNav unveils industry's lowest-power GPS RFIC

GloNav Inc. announced the volume production availability of its ultra low-power L1 GPS RFIC optimized for integration into cellular handsets, portable consumer electronic devices and battery operated GPS devices. The GNR1040 is a highly integrated, low-power, single-conversion low-IF GPS RFIC for the 1.575GHz - L1 signal that includes built-in flexibility and programmability to support multiple GPS baseband processors. *www.glonavgps.com*

Kenzi Technology launches asset tracking and security solutions

UAE based Kenzi Technology is introducing a slew of mobile asset management and asset security products. It has put up a 24 x 7 Central Command Center at their Head Office in Abu Dhabi where they are currently monitoring a large number of fleet for their clients in the UAE. They are introducing another first in the ME, a MOBILE based vehicle tracking solution that allows tracking car using mobile phone. *www.albawaba.com*

Ricoh releases GPS-ready digital camera

Ricoh Corporation, released the 500SE GPS-ready digital camera. Developed for outdoor location-based photography, its integrated precision GPS module provides for an all-in-one, easy- to-use device for geo-coding images and video at the time of capture. For higher precision application, the camera is capable of receiving NMEA data streams from external GPS devices via its on-board Bluetooth radio. *http://biz.yahoo.com*

Low-cost GPS fleet management system on Australian market

Travroute Australia Technologies announced the launch of CoPilot FleetCenter, a GPS based low-cost fleet management solution. The system can be viewed from any internet connected computer, managers can access its secure web site and view their fleet in real-time, receive automated exception alert reporting, delivery status information. *www.busnews.com.au*

Motorola provides new mobile navigation and LBS

Working with Jentro Technologies, Germany and Destinator Technologies as software suppliers, Motorola will launch new navigation products in 2007. It will be equipped with location-based services and navigation platforms that give consumers access to local point-of-interest searches, community tools and other LBS and value-added services. *www.motorola.com*

Aeroflex launches A-GPS-enabled mobile handset test platform

Aeroflex, USA has launched a fully integrated solution for testing A-GPS (Assisted-Global Positioning System) enabled mobile handsets. The solution is based on Aeroflex 6103 AIME and 6103 AIME/CT mobile handset test systems. It has been designed to address the rapidly emerging development and conformance test requirements for A-GPS-based mobile handsets by testing A-GPS implementation in the laboratory. *www.aeroflex.com*

Pharos introduces its first GPS Smartphone

Pharos Science & Applications, Inc., USA, has launched its first GPS-enabled smartphone. It offers a full-featured navigation experience on a sleek smartphone with extensive wireless options and the added convenience of a two mega-pixel camera and FM radio. *www.pharosgps.com*

GSM phone integrates GPS, 2MP camera

dmedia System Co. Ltd, Taiwan offers the GPS Phone-F2, a GSM phone that has a built-in GPS. It supports GSM 900MHz, 1800MHz and 1900MHz. It has a 2in transreflective touchscreen TFT LCD and 2MP digital camera. The phone features DGTV, radio, video and music players, as well as a photo viewer. It has a micro Secure Digital (SD) slot and touch panel.

CDMA based fleet monitoring system

Micro Technologies India Ltd has announced CDMA based Vehicle Tracking System which could be used on CDMA technology. *www.equitybulls.com*

Motorola wins Jiangsu Mobile's contract

Motorola, Inc announced that Jiangsu Mobile Communications Corporation (JSMCC), will deploy Motorola's solution for location-based mobile telecommunications services. It will provide location-based value added services to 20 million subscribers in Jiangsu province. *www.motorola.com*

Cisco enters RFID wireless location business

Cisco, USA announced a turnkey Wi-Fi Asset Tracking solution specifically geared for aerospace, automotive, mining and semiconductor manufacturing industries. By implementing Cisco's Wi-Fi Asset Tracking solution, manufacturers gain greater visibility into their enterprise, can track the presence and real-time location of high-value manufacturing assets, and substantially increase operational efficiencies by reducing misplacement incidents. *www.aeroscout.com*

GPS phones to find big market share

GPS is about to hit mobile phones in a big way, especially in Europe. Canalys, UK, a research company, found that 12 million GPS devices changed hands from supplier to consumer in the first three quarters of 2006. Canalys expects that number to hit 28 million this year. Consumers in Japan and the US see GPS more so in car units, some of which can be detached and become portable. 2007 is expected to be the first of a series of years in which GPS-enabled mobiles flood the market.

Europe and Oceania, for instance, have GSM networks that wouldn't be able to process the CDMA-standard devices that are common in the U.S. and Japan. One final assist goes to AGPS, which is assisted-GPS and is a technology fresh off the shelf that helps eliminate lag times that are so common with satellite-searching. As all of these enhancements and adjustments are incorporated and awareness of utility grows, the widespread use of GPS-enabled mobiles will skyrocket, analysts say, adding that that skyrocketing will start in 2007. *www.mobilemag.com*

BAE Systems demonstrates passive geo-location technology

BAE Systems, UK demonstrated a passive geo-location capability that enables aircraft to quickly and accurately identify enemy positions in crowded radio frequency (RF) environments. The equipment can be deployed on any type of military aircraft. The new capability, demonstrated at the US Naval Air Warfare Center Weapons Division, China Lake, California, enables aircraft to calculate geo-location with any radio frequency (RF) signal. *www.baesystems.com*

Samsung launches bluetooth navigator device

Samsung has unveiled the Bluetooth Navigator (STT-D370). It's a GPS navigator that connects a mobile phone via Bluetooth feature. The microphone and speaker phone, embedded in the product enable the users to make or receive phone calls and SMS text messages, without using a mobile phone. *www.sda-india.com*

TomTom creates embedded portable navigation solution

TomTom has developed a portable navigation device which can be embedded into vehicles through the dashboard or the radio. The new offering will see TomTom partner with car manufacturers and their suppliers to create new, smart ways to customise its navigation technology into the look and functions of their cars. *www.tomtom.com*

GeoEye appoints AAMHatch as reseller

AAMHatch is GeoEye's reseller for IKONOS and OrbView satellite imagery throughout South East Asia and the Oceania region. It is the sole GeoEye reseller in the Oceania region only but also able to sell into South East Asia.

Lisa Dykes, Remote Sensing Specialist, Manager, AAMHatch Oceania IKONOS Program shared her views with coordinates.

How do you see the market of high resolution imagery?

AAMHatch is very excited about the region we call home - the Asia Pacific - and we see the demand for high resolution imagery as being driven by the rapid expansion of our region. This increasing demand can be attributed to sustained economic and infrastructure development. The IKONOS satellite is able to offer a versatile supply of imagery which readily meets this demand.

What are the key challenges?

A major challenge is of course cloud cover; which is always an issue for spatial image acquisition in this region. As the IKONOS satellite is quite agile, there are opportunities to program capture over areas of interest. With the much-anticipated launch of GeoEye-1 later this year, there will be more image acquisition opportunities available.

Depending on the project size and location, IKONOS can offer cost effective imagery that can be utilized for much more than merely a GIS backdrop. For example, the Near Infra-Red spectrum provides insights into vegetation vigour.

What is the significance of AAMHatch being a reseller of GeoEye?

We knew that strategically it made sense to expand our service offering and link in the synergies of as many remote sensing technologies as possible. What has impressed us has been the favourable market reaction. David Jonas who leads our Asia Pacific Business Development has been contacted by many clients who are excited by this new AAMHatch service. We see our role as contributing to the overall growth of the imagery market in the Asia Pacific. Data from our LiDAR and digital cameras combine brilliantly with satellite imagery to provide clients with a multi resolution data set. We share our client's excitement about the GeoEye and AAMHatch relationship, recognising the enormous potential for high quality, cost effective datasets.

BioEnable's GPS tracking service

India-based BioEnable has launched a Web-based GPS Tracking service called GPSintegrated. The service allows real-time tracking of vehicles, assets, people, and so on. To be able to avail the service, users need to purchase a GPS tracking device, and a Web site account for reports and maps. *www.techtree.com*

NovAtel Inc. launches enclosure for its GPS/GNSS engine

NovAtel Inc. launched DL-V3 – an enclosure housing NovAtel's GPS/ GNSS OEMV-3 engine. It has features such as Bluetooth for wireless connectivity and Ethernet for remote network access, as well as a removable Compact Flash card for data security and portability. *www.novatel.com*

NATO awards GIS contract to TENET

NATO NC3 Agency has awarded the GIS Data Preparation Contract to TENET supported by Galdos Systems Inc. and IIC Technologies Inc in Canada. The project involves the generation of a wide range of geospatial data models compliant with some of the latest spatial open information standards from OGC and ISO and the conversion of many terabytes of vector, raster and gridded data. A large proportion of NATO's paper holdings of maps and charts will also be digitized and converted to the same set of open standards. The objective is to create an open and shareable map database as part of NATO core GIS infrastructure within the Alliance. At the forefront of these open standards are the two key encodings of GML and GMLJP2 to provide effective encoding for Raster and Coverage data. *www.galdosinc.com*

Nepal-China discusses boundary incompatibilities

The Joint Inspection Committee (JIC) of Nepal-China borders have agreed to further work out on incompatibilities of new data of boundary markers with data of old map attached in the 1979 protocol. The Nepalese and Chinese officials and experts discussed on improving GIS of Nepal-China boundary in December last year. The meeting decided to hold the fifth JIC meeting in China in April next year. *www.gorkhapatra.org.np*

Digital maps of Chandigarh to be online

The Department of Information Technology has decided to digitise the maps of Chandigarh. The new digitised maps will also include the Phase-III sectors which are sectors 48 to 56, Modern Housing Complex, Manimajra, Sector 38 West etc. A GIS will be prepared on the Estate Office and the soft copy map along with the database will be hosted on the National Informatics Centre (NIC) Headquarters server at New Delhi, which will be further published on web portal of Chandigarh Administration. *http://cities.expressindia.com*

OGC becomes member of World Wide Web Consortium

The OGC recently became a member of the www Consortium, (W3C, www.w3.org) a standards organization that develops interoperable technologies (specifications, guidelines, software, and tools) to lead the Web to its full potential. *www.opengeospatial.org*

Infoterra to assist VLAP

Infoterra Ltd has been appointed to provide technical assistance to the Government of Vietnam in the development of a proposal for the first phase of the Vietnam Land Administration Project (VLAP). Appointed by SIDA/The Swedish Embassy in Hanoi, Infoterra's team will work in close co-operation with the Ministry of Natural Resources and Environment (MoNRE) and other Government of Vietnam agencies. *www.infoterra.co.uk*

Monorail network for Saudi Arabia

Jeddah needs a network of monorails has been the recommendation of a study conducted by the Faculty of Environmental Design of King Abdul Aziz University in Jeddah. The main objective of the study was to find a mechanism for planning and operating a railway network in the city. *www.khaleejtimes.com*

India to make all land records online

Beginning the next financial year, the Department of Land Reforms under the Ministry of Rural Development, Government of India, will launch a Comprehensive Modernisation of Land Records (CMLR) that will make all land records in the country online by the end of 11th Five-year plan. Under the scheme, all records for land and all other immovable properties would be computerised using aerial survey and digital mapping. *www.indianexpress.com*

Home-made GIS software (in China) has edge on market

China's market share of most domestically produced software accounts only about 5 percent in such fields as operating system, database, and office software while domestic GIS software is over 35 percent, outshining all others, thus having broken the monopoly of foreign software in that field.

Geospatial Linking Service Interoperability Experiment

Open Geospatial Consortium Inc. (OGC) will launch an Interoperability Experiment on Geospatial linking. This Experiment will test methods for linking attribute data to those data records' geospatial representations (typically stored as digital maps) when both data and geospatial representations are stored at separate locations on the Internet. The experiment is expected to validate the functions of Web services specified in the "Geospatially Linked Data Access Service (GDAS)" and "Geospatial Linking Service (GLS)". The initiators of the Interoperability Experiment are: Natural Resources Canada (Geoconnections), University of Nottingham, Safe Software Inc., and Graphical Data Capture Ltd. Other organizations are encouraged to participate in or sign on as observers for this Interoperability Experiment.

Free Elshayal Smart GIS Editor

This Arabian GIS software was developed by an Arabian developer's team, independent of commercial software packages containing most of features of conventional GIS softwares like View and Edit shape files, build new layer, add existing layer, remove layers, swap layers, save layer, edit data table, modify table structure, edit map features, drawing new features, GPS, 3D, etc. *www.smartwebonline.com.*

US expresses concern over satellite-killing test by China

The USA, Australia and Canada have voiced concerns to China over the first known satellite-killing test in space in more than 20 years. The capability demonstrated by China was no surprise to the Bush administration, which revised U.S. national space policy in October to assert a right to deny space access to anyone hostile to US Interests. The US has been researching satellite-killers of its own, experimenting with lasers on the ground that could disable, disrupt and destroy spacecraft. *http://news.scotsman.com*

Cartosat-2 beams first images

The first imagery from the panchromatic camera on board India's latest remote sensing satellite Cartosat-2 covered a length of 240 km from Paonta Sahib in Shivalik region to Delhi, Indian Space Research Organisation (ISRO) said. "Another set of imagery of about 50 km length covered Radha Nagari to Sagoan in Goa before the satellite passed over the Arabian sea.

The camera was switched on at 10.05 am through a series of commands issued from the spacecraft control centre of ISRO Telemetry, Tracking and Command Network (ISTRAC) in Bangalore. *www.isro.org*

Thailand's first Earth observation satellite to be launched

Thailand's first Earth observation satellite, called THEOS, is being readied for launching into orbit in October this year, said Science and Technology Minister Yongyuth Yuthavong. The THEOS project represents a co-operation of the Ministry of Science and Technology and the contracted French company EADS Astrium. *www.bangkokpost.com*

2.5 meter resolution imagery for Google Earth

Spot Image has entered into an agreement with Google to improve the available resolution of Google Earth products. It will provide Google Earth with 2.5 meter resolution imagery taken from the SPOT5 satellite. Users will be able to see new high resolution satellite images on Google Earth for France, Belgium, Luxemburg, Spain and Portugal etc. *www.spotimage.fr*

GeoEye's next-generation satellite reaches major milestone

GeoEye, the commercial satellite imaging company, has announced the delivery of the camera for its next-generation commercial imaging satellite to General Dynamics Advanced Information Systems in Gilbert, Arizona for integration into the GeoEye-1 satellite. GeoEye-1 will be the world's highest resolution commercial imaging satellite. ITT (Rochester, New York) built the sensor, optical telescope assembly, detectors and focal plane assembly, and the high-speed digital processing electronics. It is the most important component of GeoEye-1. The satellite is anticipated to collect more than 700,000 square kilometers of high-resolution imagery every day. *www.geoeye.com/*

DigitalGlobe partners with Lowrance

DigitalGlobe is partnering with Lowrance, a brand in marine electronics since 1957, and GPS navigational systems since 1992. Under terms of the partnership it will provide satellite imagery for the Lowrance iWAY 600C portable navigation device (PND). It will be the first portable navigation device to give drivers unparalleled access to high resolution commercial imaging system. *http://media.digitalglobe.com*

ISRO scientists to begin radar mapping of ancient university

Scientists from the Indian Space Research Organisation (ISRO) have been asked to help explore ruins in and around the ancient Nalanda University in the state of Bihar, India. P.K. Mishra, Superintending Archaeologist of the Archaeological Survey of India (ASI), Patna circle, said the radar mapping would help to explore the ruins for further excavation. *www.andhracafe.com*

Terrorists using Google map to hit UK troops

British army intelligence sources have said that terrorists attacking British bases in Basra, Iraq, were using aerial footage displayed by the Google Earth to pin point their attacks. Documents seized during raids on the homes of insurgents uncovered print outs from photographs taken from Google.

The satellite images show in detail the buildings inside the bases and vulnerable areas such as tented accommodation, lavatory blocks and where lightly armoured Land Rovers are parked. Written on the back of one set of photographs taken of the Shatt al Arab Hotel, headquarters for 1,000 men of the Staffordshire Regiment battle group, officers found the camp's precise longitude and latitude.

China to launch 6 geographical survey satellites

The China Center for Resources Satellite Data and Application (CCRSDA) will launch six geographical survey satellites in five years. The center will also establish a high-resolution land observation project and build a data center for the satellites. The CCRSDA completed China's first application system for resources satellites in August 1999 followed by launch of CBERS-1, the first in a series of earth resources satellites, two months later. Data from the satellites has been used in agriculture, forestry, city planning, environmental protection and disaster monitoring.

Google Earth agrees to blur pix of key Indian sites

President APJ Abdul Kalam's concerns over Google Earth providing detailed and unhindered view of 'sensitive' Indian establishments have been addressed, courtesy a formula which allows users uninterrupted access to the 'eye in the sky' while camouflaging key installations. Fuzzy, low resolution pictures and distorted building plans is how the government and Google Earth have agreed to get around concerns that images of sensitive military and scientific establishments available on the Web could either allow unauthorised snooping or become a ready reckoner for terrorists.

At a recent meeting between ministry of science and technology officials and Google Earth representatives, it was decided that installations identified by government would be carefully camouflaged. This, it was felt, was better than an outright blackout. Besides well-known sites like BARC, there are many less prominent ones, and blacking them out would only attract attention to them. Images of these locations will not be of more than 25-50 metre resolution, more like the older generation pictures provided by Indian Remote Sensing satellites. Official sources said Google Earth would distort building plans by adding structures where none existed or masking certain aspects of a facility. This could be done without attracting attention to such establishments, which range from laboratories, mines, military sites, space and atomic centres and residences of high-profile VVIPs. *www.timesofindia.com*

MARK YOUR CALENDAR

February 2007

GlobalGeo - 3rd Geomatics and Geotelematics International Show
20 - 22 Feb, 2007 Barcelona, Spain
www.globalgeobcn.com

March 2007

Munich Satellite Navigation Summit 2007
6 - 8 March 2007, Munich, Germany
info@munich-satellite-navigation-summit.org

GEOFORM+ 2007
13-16 March, Moscow, Russia
http://www.geoexpo.ru/defaulteng.stm

3rd Asian Space conference
21-23 March, Singapore
http://pdcc.ntu.edu.sg/ASC2007/

April 2007

63rd Annual Meeting, Featuring New Bio Navigation Workshops
April 23-25, 2007, Cambridge, MA
www.ion.org

2nd National GIS Symposium in Saudi Arabia
23-25April, 2007 Al-Khobar, Saudi Arabia
info@saudigis.org.
http://www.saudigis.org/

May 2007

Spatial Sciences Institute Biennial International Conference
14-18 May, Hobart, Tasmania, Australia
www.ssc2007.com

TIDES 2007 - 5th Taipei International Digital Earth Symposium
15-18 May, Taipei, Taiwan
derc@mail.pccu.edu.tw.

Intergraph 2007
21-24 May, Nashville, Tennessee, USA
http://www.intergraph2007.com

International Conference on Integrated Navigation System
28-30 May, Saint Petersburg, Russia
elprib-onti@telros.net

Geoinformation for Disaster Management (Gi4DM2007)
23-25 May, Toronto, Canada
junli@ryerson.ca

5th International Symposium on Mobile Mapping Technology
28-31 May, Padova, Italy
naser@geomatics.ucalgary.ca

June 2007

Rivers 2007
6-8 June, Kuching, Sarawak, Malaysia
rivers2007@gmail.com.

21st Pacific Science Congress
12-16 June, Okinawa, Japan
psc21@to.jim.u-ryukyu.ac.jp.

27th ESRI International User Conference
18-22 June San Diego, California USA
www.esri.com

Geoinformation Forum Japan
20-22 June, Pacifico Yokohama, Japan
geoforum@jsurvey.jp

July 2007

Cambridge Conference 2007
15-20 July Cambridge, UK
www.ordnancesurvey.co.uk/

Asia Oceania Geosciences Society, 4th Annual Meeting
30 July – 3 August, Bangkok, Thailand

August 2007

7th International Workshop of Geographical Information System
1-3 August Beijing, China
iwgis@lreis.ac.cn

XXIII ICA International Cartographic Conference
4-10 August, Moscow, Russia
info@icc2007.com.

ISPRS Workshop on Updating Geo-spatial Databases with Imagery
28-29 August, Urumchi, Xinjiang, China
jjie@nsdi.gov.cn, jiangjie_263@263.net.

2nd Indonesian Geospatial Technology Exhibition
29 August - 1 September
Bakosurtanal; Jakarta
http://www.geospatial-exh.com/

September 2007

ION GNSS 2007
September 25-28, 2007, Ft. Worth, TX
www.ion.org

October 2007

Nav 07 - The Navigation Conference and Exhibition
30 Oct 2007 -01 Nov 2007
www.rin.org.uk
conference@rin.org.uk

November 2007

ISG/GNSS 2007
6-8 November, Kuala Lumpur, Malaysia
md.nor@fksg.utm.my

WG I/6 Workshop on Remote Sensing Applications
13-16 November, Kuala Lumpur, Malaysia
mazlan@fksg.utm.my

Keep your database up-to-date

Leica MobileMatriX has been developed for seamless dataflow between field and office, and was designed specially for the needs of field surveyors and GIS data collectors. Now it is possible to seamlessly extend the office database into the field, with direct interfaces to Total Stations (TPS) and Global Positioning System (GPS) sensors. All surveyed and collected data is automatically stored into the ESRI® Geodatabase format, eliminating the need for data conversion when moving data between Leica MobileMatriX and ArcGIS™ databases. To update the office database, simply use the synchronization mechanism to transfer the data from office to field and vice-versa. To ensure maximum compatibility with all systems, Leica MobileMatriX allows the user to interact with data from different CAD packages and other GIS office solutions.

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