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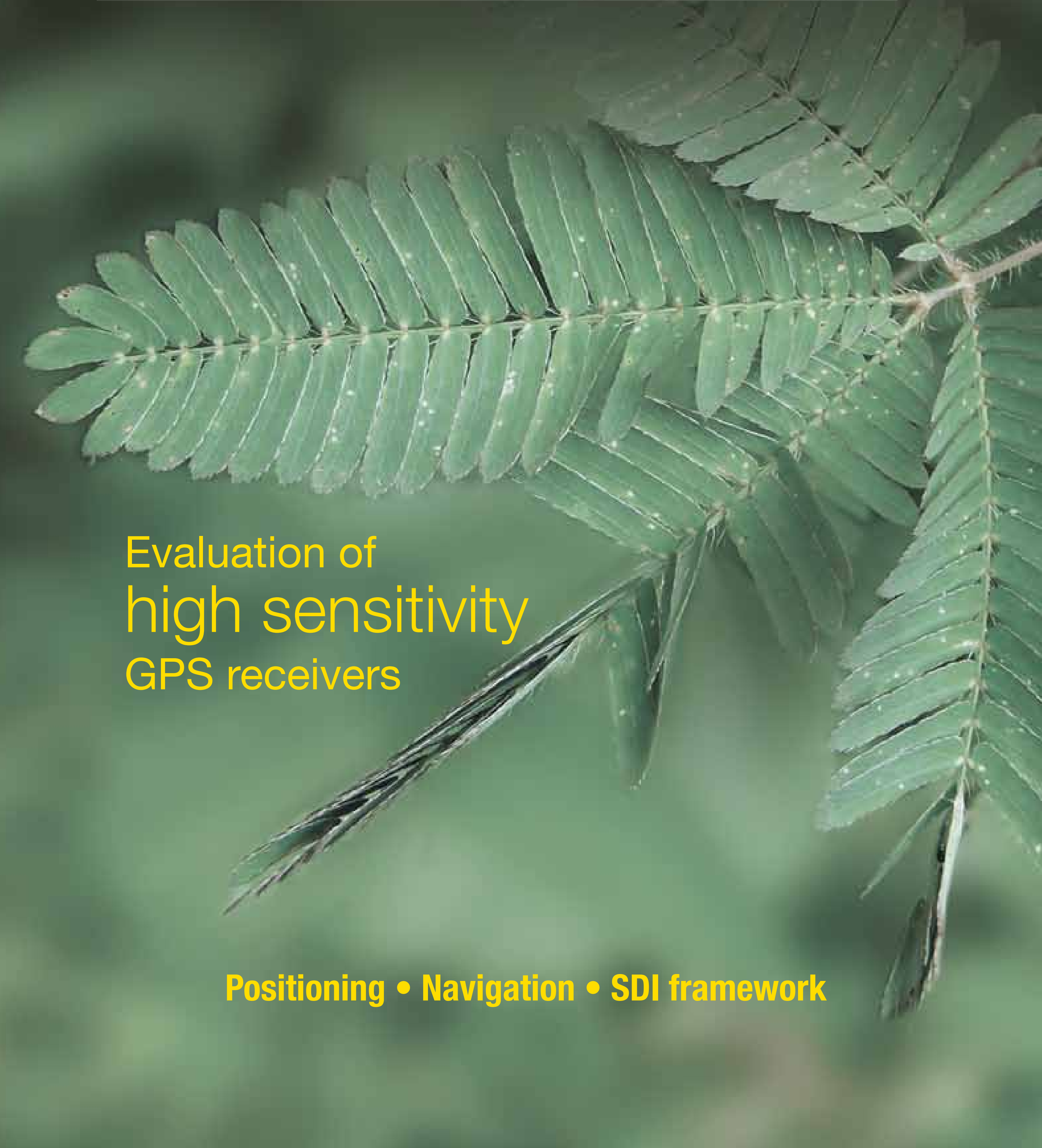

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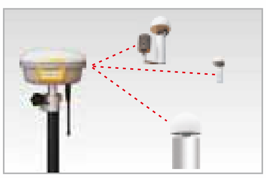

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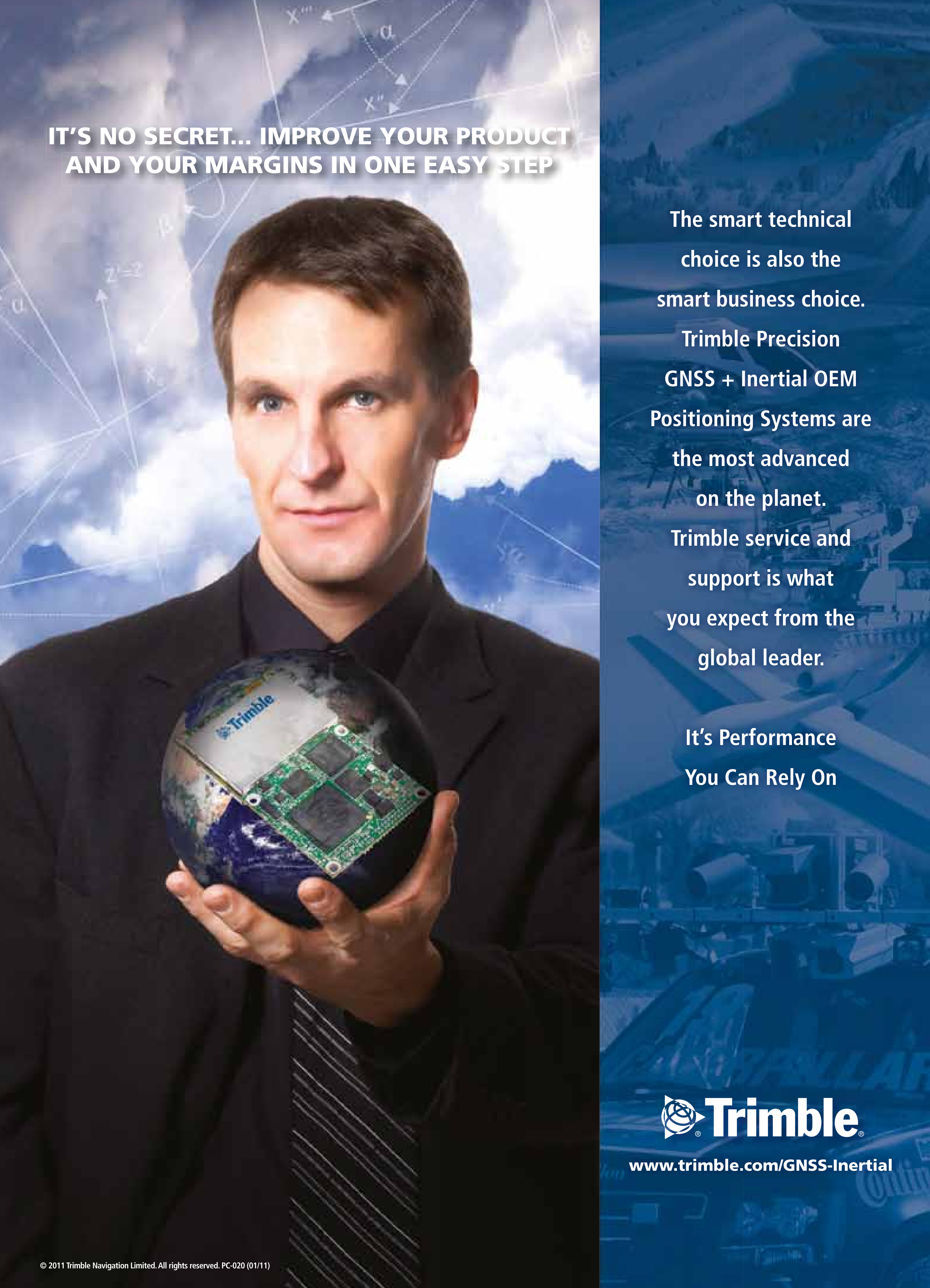
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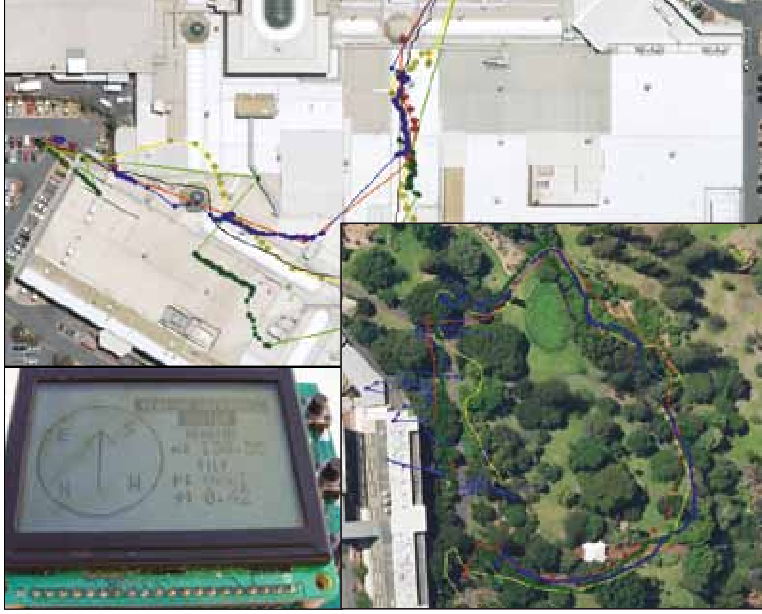

In this issue

Coordinates Volume 7, Issue 3, March 2011

Articles

Columns

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GNSS pulse

The USA moves ahead with GPS III.

China takes a leap forward with five satellites of COMPASS last year.

And promises four more this year.

GALILEO appears for a compromise of 18 satellites as of now.

And Japan assures of a steady progress with MICHIBIKI in place.

GLONASS suffers a massive setback with of loss of three satellites.

But the zeal continues with GLONASS K in place.

Many such voices were made and heard.

At recently held Munich Satellite Navigation Summit in Germany.

And also was heard.

A loud silence on Indian Regional Navigation Satellite System.

Bal Krishna, Editor
bal@mycoordinates.org

Evaluation of high sensitivity GPS receivers

The performance of the receivers from different manufacturers varies – one receiver may perform very well in one aspect, but not that as well against other criteria. There is no single clear "winner" on the HSGPS receiver market.

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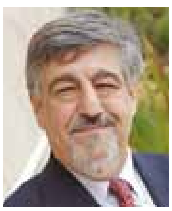

Chris Rizos
School of Surveying and Spatial Information System, UNSW, Australia

The year 1978 saw the launch of the first Global Positioning System (GPS) satellite. Today, GPS, as the first and currently only operational global navigation satellite system (GNSS), is widely used and is a vital technology for many of society's economic, scientific and social activities. Applications can be found everywhere, such as spacecraft navigation, geodesy, surveying and mapping, precision navigation, machine guidance, vehicle fleet management and "intelligent transport systems" (ITS), emergency services and "location based services" (LBS). Clearly the development of GPS has revolutionised what are now termed "positioning, navigation and timing" (PNT) activities. Although GPS will soon be joined by the next operational GNSS – Russia's GLONASS, as well as two future competitors – Europe's GALILEO and China's COMPASS – GPS dominates the world GNSS market. This is especially the case as far as the mass market ITS and LBS applications are concerned. All new smartphones have a built-in GPS chipset.

GPS works fine everywhere where there is clear sky, so that at least four direct (line-of-sight) GPS signals can be received. However, in many difficult signal environments –where the satellite signals are weak (<-172dBW) and multipath is severe, such as urban canyon and indoors – a conventional GPS receiver often fails. So-called "high sensitivity" GPS (HSGPS) receivers have been developed to improve PNT availability under difficult signal environments. In addition, many HSGPS receivers accept "assisted GPS" (A-GPS) messages in order to reduce the time-to-first-fix (TTFF) and possibly increase the sensitivity even further. There are a number of HSGPS receivers available on the market, and their performance, in terms of TTFF and accuracy, does vary.

After a brief review of HSGPS receivers and A-GPS principles, this paper evaluates several HSGPS receivers: ublox LEA-4P, Navman Jupiter 32, ublox EVK-5H and SiRF GSCI-5000. Several tests were carried out, one is a static test, for which an Open Source GNSS Reference Server (OSGRS) was used to provide the A-GPS assistance messages. Kinematic tests were also conducted, in which the receivers were installed on a car to test their performance in urban canyons. Several mobile phones, e.g. Nokia N95, HP iPaq 914c, iPhone 3GS and iPhone 4, were also tested. The TTFF, positioning accuracy and the sensitivity to weak signals was investigated.

High Sensitivity GPS and Assisted GPS

There are two fundamental operating modes of GPS receivers; the first is normally termed "acquisition", and the second is "tracking". The latter then enables "positioning" if enough satellites (a minimum of four satellites in the case of 3D positioning) can be tracked, providing a position, velocity and time (PVT) solution. A receiver will remain in this state until it is either turned off or cannot track enough satellite signals.

In the acquisition mode, (if no assistance data can be obtained) the receiver first assumes that a satellite is visible and a channel is allocated for this satellite. There are two search unknowns: the exact frequency of each satellite carrier frequency which is changed by any Doppler shift, and the alignment of the receiver and transmitted pseudo-random number (PRN) codes [1]. The Doppler frequency shift is caused by the relative movement of the receiver and the satellite, as well as any drift in the receiver oscillator. Since the Doppler is unknown, the receiver must search across a wide frequency range, typically 30 or more Doppler "bins". If using time-domain acquisition, the receiver will try to align the local PRN code generated by the receiver with that transmitted by the satellite. It typically takes one or more seconds to search each Doppler bin [2].

After a satellite signal has been acquired, it can be tracked and the receiver decodes the broadcast navigation data: the time, the orbit ephemeris, the almanac, and other data. The almanac is used to identify the locations (and Doppler shifts) of the other satellites in the GNSS constellation. The ephemeris of each satellite must be obtained to calculate a PVT solution. It takes between 18 to 30 seconds (depending on the start point for decoding) to extract the ephemeris information from the modulated navigation message. However, if there are signal dropouts or loss of any data bits in the message, it takes a much longer time to extract the complete navigation message. In a very difficult signal environment it may even be impossible to perform this decoding operation in a conventional GPS receiver.

GPS signals are very weak when they arrive at the Earth's surface. The transmitters on the GPS satellites only deliver 27W from a distance over 20,000km in orbit above the Earth. By the time the signals arrive at the user's receiver, the maximum received signal level is not expected to exceed -153.0dBW, and typically is as weak as −158.5dBW [3]. This is well below the thermal noise level for the signal bandwidth. The received signal strength can be classified into three categories [4]:

Strong signal strength: > -172dBW. Receivers have a clear view of the sky, operating in open fields or in low rise residential areas.

Weak signal strength: -172dBW to -180dBW. Environments are very noisy, such as in forests under dense tree foliage, indoor environments near windows, and urban canyon areas.

Very weak signal strength: -180dBW to -190dBW. Only very weak reflected and multipath signals can be tracked, examples are inside office buildings and multistorey car parks, or where receivers are operated well away from windows and doors.

Conventional GPS receivers work well in strong signal environments, but have difficulties, or simply do not work at all, in weak and very weak signal environments.

There are two common ways to improve the "sensitivity" of a GPS receiver. One is simply to increase the time for the integration within the receiver of the received signal. Conventional GPS receivers integrate the received GPS signals for 1 ms, which is the duration of a complete C/A code cycle. This limits the ability to acquire and track signals, only able to operate with signal strengths down to around the -160dBW level.

The integration time can be increased up to 20ms. The ability to predict a bit transition in the navigation message makes possible much longer coherent integration, say several hundreds or even up to a thousand milliseconds. The use of non-coherent integration techniques can help overcome the problem [5] [6]. However, only increasing the integration time may lead to an intolerably long searching period. Increasing the number of the correlators enables the use of fast and "deep" GPS signal search techniques [6]. For example, the ublox-5 chip has more than a million correlators [7].

A-GPS is a term closely linked to HSGPS. The common messages used for A-GPS are [8] [9]:

- GPS initial data, including time, position

Device	GPS Chipset Manufacturer	Year of Manufacture
ublox LEA-4P [12]	ublox	2005
Navman Jupiter 32 [13]	Navman (SiRF)	2006
ublox EVK-5H [7]	ublox	2007
SiRF GSCI-5000 [14]	SiRF	2006
iPhone 3GS	Infineon (Hammerhead II) [15]	2009/2007
HP iPaq 914c	Qualcomm (MSM6280) [16]	2005/2004
iPhone 4	Broadcom (BCM4750UBG) [17]	2010/2008
Nokia N95	Texas Instruments (GPS5300 NaviLink™ 4.0) [18]	2007/2005

Table 1. List of the testing devices

No.	Point	Description	Type
1	HP415	nearby 9 storey building	Urban
2	B609	distant 4 storey, 6 storey and 11 storey buildings, partial tree cover	Urban
3	B406	nearby 6 storey building	Urban
4	DH803	indoor (carpark)	Indoor
5	INDR5	residential living room	Indoor
6	INDR6	lecture room	Indoor

Table 2. Details of the UNSW test positions

Figure 1a. HSGPS receivers used in the tests (from left to right, top to bottom: ublox LEA-4P, Navman Jupiter 32, ublox EVK-5H and SiRF GSCI-5000)

Figure 1b. Mobile phones used in the tests (from left to right, top to bottom: iPhone 3GS, HP iPaq 914c, iPhone 4, and N95)

- GPS health, UTC and ionospheric model parameters
- Almanac data
- Ephemeris data

This information can be used to assist in the detection of signals from the visible satellites by allowing for the calculation of the exact frequency of each satellite carrier signal due to Doppler shifting. However the alignment of the PRN code between receiver and satellite requires very accurate time (much better than 1ms), which is normally not available. A-GPS can improve the TTFF, increase the signal sensitivity and hence increase the signal availability [10].

The Open Source GNSS Reference Server (OSGRS) provides an alternative to commercial A-GPS reference data solutions. The OSGRS is a Java application that provides data for Assisted-GPS/GNSS clients. It is cross-platform and provides client applications with current, relevant and specific assistance data. The GNSS Reference Interface Protocol (GRIP) is utilised by OSGRS. GRIP defines the structure of the HTTP POST request, as well as the structure of the XML document in the body of the request [11]. The OSGRS was used in the HSGPS tests reported here.

Device description

Eight HSGPS receivers/mobile phones were used in the tests (Table 1 and Figures 1a, 1b). Mobile phone manufacturers use the GPS chipsets on the market, though there is generally a two year gap between the announcement of the phone (Table 1 column 3, the first date) and the release of the GPS chipset (Table 1 column 3, the second date).

All devices were A-GPS enabled. In the HSGPS receiver documentation the commands used for A-GPS can be found (typically proprietary binary protocols) [9] [19] [20] [21]. However, it is extremely difficult, if not impossible, to access the built-in GPS chipset. Hence only four HSGPS receivers could be tested in A-GPS mode.

Static test results

Six test positions with known coordinates were selected around the University of New South Wales (UNSW) campus. Fig. 2 shows some test positions, the picture in the middle also illustrates the typical setup of the A-GPS test. A broad range of environments can be found in the campus. All six test positions are either located in urban-like environment or indoors. Table 2 gives details of the test points.

At each test position one standalone HSGPS receiver (the ublox5) was tested. 100 "cold starts" were requested by the test software, and data were logged on a laptop computer. To average out the influence on the results of the number of visible satellites and their geometric distribution, the 100 cold start tests at each test position were conducted in four groups; each group consisting of 25 tests. All four HSGPS receivers were tested in the A-GPS mode. The OSGRS was used to provide the assistance messages. There were a total of 4 times 600 location results (at 6 test positions) for the A-GPS tests.

Figure 2. The test environment – from left to right, test position 1, 4 and 6 (the picture of test point 4 also shows the typical setup of the standalone HSGPS test and A-GPS test)

Table 3 summarises the test results. The ublox EVK-5H receiver was chosen for the standalone test as it performs the best among the four HSGPS receivers available. In fact its performance is very good under the difficult environments. The average TTFF was as short as 36.5s and the average number of satellites used for positioning is 5. The horizontal and vertical errors are 23.3m and 29.5m respectively. The failure rate is only 23%. Test failure is defined in two ways:

Failed test type I: A test where the receiver failed to report the position within the predefined time interval (60s)

Failed test type II: A test where the provided position is grossly in error (the criterion is horizontal distance error greater than 550m)

When assistance was provided, the ublox EVK-5H receiver performed better. The average TTFF decreased to about 2016s and the average number of satellites increased to 6.2. The positioning accuracy was about the same, while the failure rate drops significantly to 9%. The performances of the other HSGPS receivers vary. For example, the SiRF GSCI-5000 performed the best in terms of TTFF – only 11.8s on average; however the average positioning accuracy was the worst. This suggests that there is a trade-off in receiver design between signal sensitivity and positioning accuracy [22].

Figure 3. Kinematic test of HSGPS receivers (Navman – yellow circle; SiRF – green triangle; ublox 4 – red cross; ublox 5 – blue square; real ground track – white; start point – red star; end point – green triangle)

Kinematic test results

Tests of the HSGPS receiver

A car equipped with the four HSGPS receivers (see picture on the right upper corner of Fig. 3, antennas installed on the car roof) was driven around the Sydney CBD. Fig. 3 displays the tracks reported by the receivers (plotted on Google Earth). The two pictures on the right side show the test environment – high rise buildings block most of the sky. Under this harsh signal environment, HSGPS receivers could still provide reasonable solutions. The shape of the track is correct. The largest offset error is at the left upper corner where all the receivers report position with errors of over 100 metres – possibly caused by severe multipath. The average number of used satellites were 6.5 (ublox5), 6.5 (ublox4), 5.2 (SiRF) and 5.6 (Navman). Note that ublox also utilises SBAS (Satellite Based Augmentation System). In this test, two MTSAT (PRN 129 and 137) were tracked and used (if possible) in position calculations. This may explain the better performance of these two ublox receivers.

Tests of mobile phones

The tests of mobile phones were carried out for three scenarios: urban canyon, shopping centre, and an area under dense tree foliage. Four handsets were held by two persons walking along the same paths. The software "EasyTrails" was used on the iPhone 3GS and iPhone 4 for the tests; "Sports Tracker" from the Nokia Ovi Store was used on the N95, and a small application was developed for Windows Mobile, the HP iPaq device.

Fig. 4 displays the tracks obtained in the urban canyon test environment. Comparing with the kinematic test of the HSGSP receivers, this test environment is less harsh. The performances of the mobile phones were not bad – the maximum offset of the tracks reported by the handsets was about 50 metres. The effects of multipath disturbance were also evident.

Fig. 5 shows the tracks reported by the mobile phones in the shopping centre test. It can be seen that at some areas in the shopping centre the mobile phones could report positions. The synthetic glass roof above those areas allowed satellite signals to pass through. The HSGPS chipsets could utilise the signals to calculate a PVT result. In the area covered by a concrete roof, all satellite signals were blocked, or attenuated too much, and the mobile phones could no longer provide a PVT solution. Although the accuracy of the positioning results were in general not very good, it was impressive to see the mobile phones actually working within a shopping centre environment. The iPhone 4 performed best in this test.

Fig. 6 displays the results of the test scenario under tree foliage. In general this scenario was less challenging than the other two. The green track generated by the N95 is close to the real ground track. Other handsets also performed well, with the exception at some places. As in previous tests, the iPhone 3GS provided sparse PVT solutions. The positioning result from the iPaq was quite variable, while that from the iPhone 4 exhibits an offset (of about 20 metres) at the beginning of the test which may be caused by multipath from a nearby multistory building.

Conclusions

HSGPS receivers are widely used for many mass market applications. Under harsh signal environments, the HSGPS receivers can still provide PVT solutions, although the accuracy is not as good as in clear sky conditions. From the tests, one can observe that, in general, the newer receivers performed best. The performance of the receivers from different the manufacturers varies – one receiver may perform very well in one aspect, but not that as well against other criteria. There is no single clear "winner" on the HSGPS receiver market. However, with technological advances a better HSGPS receiver can always be expected to be released.

Test	Receiver	Horizontal error (m)	Vertical error (m)	TTFF (s)	Average No. of Satellites	Failure rate (%)
Standalone	ublox EVK-5H	23.3	29.5	36.5	5.0	23
A-GPS	Navman Jupiter 32	18.4	26.4	24.8	5.2	13
	SiRF GSCI-5000	53.4	61.2	11.8	4.7	7
	ublox LEA-4P	27.8	42.5	30.8	4.7	42
	ublox EVK-5H	21.9	32.5	20.6	6.2	9

Table 3. Summary of standalone GPS performance and A-GPS performance of different receivers using OSGRS

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Figure 4. Kinematic test results of HSGPS receivers in an urban canyon environment (iPhone 3GS – red cross; iPhone 4 – yellow diamond; iPaq 914c – blue dot; N95 – green square; real ground track – white; start point – red star; end point – green triangle)

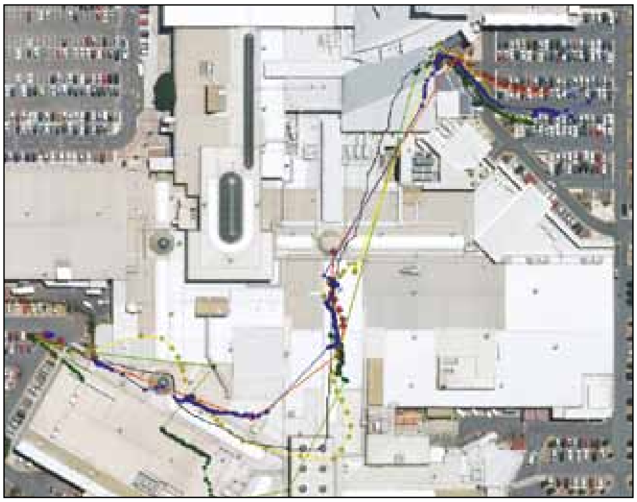

Figure 5. Kinematic test results of mobile phones in a shopping centre (symbols are the same as in Fig. 4, except real ground track – white); the right bottom corner shows the interior test environment

Figure 6. Kinematic test results of mobile phones in a forested area (symbols are the same as in Fig. 4, however there is no real ground track to provide "groundtruth")

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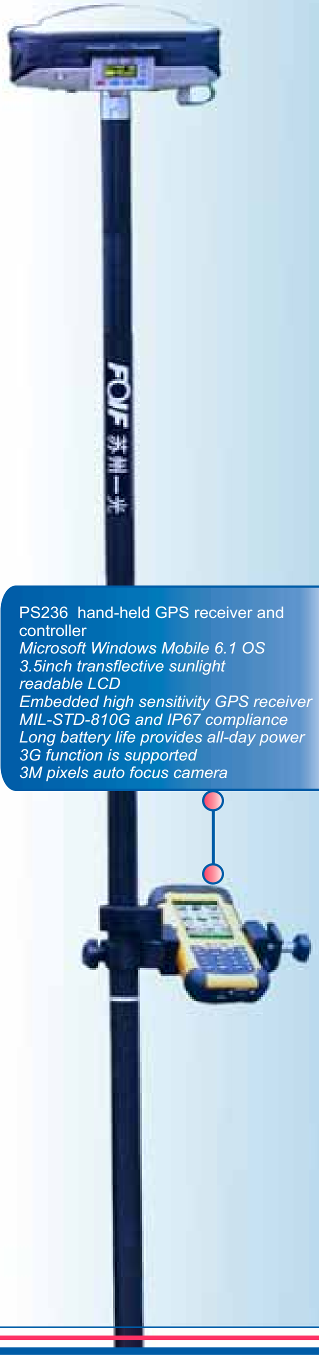

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Operation and implementation of heading reference system

This article presents a project and hardware design of HRS system, utilizing an electronic compass with tilt sensors and a gyro

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Whenever there is a need for continuous navigation, radio-technical systems are usually integrated with inertial navigation systems (INS) or dead-reckoning systems (DR). Due to large dimensions and power consumption, as well as high prices, INS systems have been traditionally applied in high-end or military applications. Recently an unprecedented decrease of all the above mentioned factors have been witnessed, making inertial navigation suitable for a wider set of applications. However, the dead-reckoning method is still the preferred choice in low-cost land navigation systems.

Dead Reckoning (DR) allows to determine the current position of a vehicle using heading and velocity measurements. One of the data streams needed for DR can be provided by the Heading Reference System (HRS). The HRS provides heading estimates, which allow DR to calculate the direction of a vehicle displacement and, along with velocity information, to predict the current position of the vehicle.

This article presents a project and hardware design of HRS system, utilizing an electronic compass with tilt sensors and a gyro. These additional sensors are used to correct the compass measurements. The main task of the developed system is to determine the current heading on the almost continuous basis and with as high accuracy as possible.

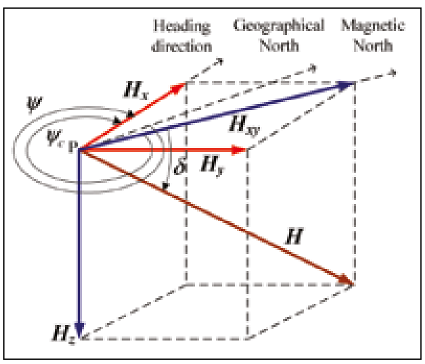

Fig. 1 Earth's magnetic field and magnetic azimuth

Magnetic azimuth

The main subsystem of the designed HRS is an electronic compass module. It allows heading estimation, based on the Earth's magnetic field measurements.

To determine the magnetic heading, the components of Earth's magnetic field have to be measured in two orthogonal, parallel to the Earth's surface, directions. The three dimensional Earth's magnetic field vector and its relationship with the magnetic azimuth is shown in Fig. 1 [1, 2].

The Earth's magnetic field vector consists of the vertical component $\boldsymbol{H}_z$ and the horizontal component $\boldsymbol{H}_{xy}$. The direction of the $\boldsymbol{H}_{xy}$ vector is parallel to the magnetic North-South direction. Next, the horizontal component vector $\boldsymbol{H}_{xy}$ can be shown as a sum of two vector components: $\boldsymbol{H}_x$, which is parallel to the movement direction and $\boldsymbol{H}_y$, which is perpendicular to the movement direction. It has been assumed that the positive values of these components correspond with the forward sense of the $\boldsymbol{H}_x$ vector and the right sense of $\boldsymbol{H}_y$ vector. As can be seen in the Fig. 1, the magnetic azimuth can be calculated as follows [1, 2]:

$$\psi_c = 2\pi - \text{atan}\,(H_y/H_x) \quad (1)$$

As can be seen in the equation (1), it is sufficient to measure only two horizontal components of the Earth's magnetic field to calculate the magnetic azimuth. One should take into consideration that it is crucial to measure the horizontal components. That is the reason why the magnetic sensors in the compass module should be gimballed mechanically or electronically.

Electronic gimballing

When the compass module is tilted, the measured components do not equal horizontal components of the Earth's magnetic field [5, 6]. Because of that, the angle determined with the use of the equation (1) is sensitive to the tilt of the compass. The influence of the tilt angle τ and the inclination angle δ (see Fig. 1) on the azimuth error are shown in Fig. 2.

As can be seen in Fig. 2, the azimuth error can achieve large values, up to 40°, even for relatively small tilt angles, such as 10°. The ε error tends to grow fast for increasing tilt angles and its maximum value depends on the inclination angle δ. Such high error values are not allowable.

Electronic tilt compensation has been applied to reduce compass tilt errors in the designed HRS. Fig. 3 shows pitch and roll angles of the electronic compass module [2, 4].

The coordinate frame defined by the X_C, Y_C and Z_C axes is aligned with the compass module. The normal vector of the other coordinate frame defined by the axes X_E, Y_E and Z_E is the gravity vector thus its OX_EY_E plane is horizontal. The tilt angle measured between X_C axis and the plane E is the pitch angle θ and the angle measured between Y_C axis and E plane is the roll angle ϕ.

The measurements of magnetic field components in $X_CY_CZ_C$ frame should be transferred to the $X_EY_EZ_E$ frame to compensate tilt effects. The values of magnetic field horizontal components in OX_EY_E plane can be determined using the following equations [1, ,3 ,4]:

$$H'_x=H_x\cos\theta-H_y\sin\phi-H_z\sin\theta\cos\phi \qquad (2)$$

$$H'_y=H_y\cos\phi-H_z\sin\phi \qquad (3)$$

To evaluate the above equations the vertical component $\boldsymbol{H}_z$ of the Earth's magnetic field as well as pitch and roll angles of the compass module have to be known. The vertical component is measured using an additional magnetic field sensor and tilt angles are measured with the use of a 3-axis accelerometer.

The method of calculating these angles makes use of the measurements of the Earth's gravity acceleration vector along X_C, Y_C and Z_C axes: (fig 4).

On the basis of Fig. 4 tilt angles can be calculated using the following equations [2, 3]:

$$\theta = \mathrm{atan}\left(a_x \Big/ \sqrt{a_y^2 + a_z^2}\right) \qquad (4)$$

$$\phi = \mathrm{atan}\left(a_y \Big/ \sqrt{a_x^2 + a_z^2}\right) \qquad (5)$$

When H'_x and H'_y magnetic field components are known, tilt compensated azimuth can be determined as follows:

$$\psi_M = 2\pi - \mathrm{atan}\,(H'_y/H'_x) \qquad (6)$$

Gyroscope correction

The designed Heading Reference System uses a one axis gyroscope sensor which provides information about angular rate and the change of the total angle. Its sensitivity axis is aligned with the Z_C axis of the compass module.

To determine the gyroscope heading ψ_g, angular rate measurements ω_g from gyro have to be integrated which leads to accumulation of errors with the rate depending on the drift of the sensor. Moreover heading calculated on the basis of gyroscope measurements has to be initialized. In the design, the initialization is performed during the start-up procedure of the device and ψ_g is set to the initial compass azimuth $\psi_c(0)$. The gyroscope heading can be calculated using the following equation:

$$\psi_g(n) = \psi_c(0) + \sum_{k=1}^{n} \Delta\psi_g(k) \qquad (7)$$

It should also be noticed that in case of deflection of the system's vertical axis from the normal to the Earth's ellipsoid, the angular velocity sensed by the gyro will be smaller than the true one. To make the correction of the angular velocity, inclination sensors should be installed in the

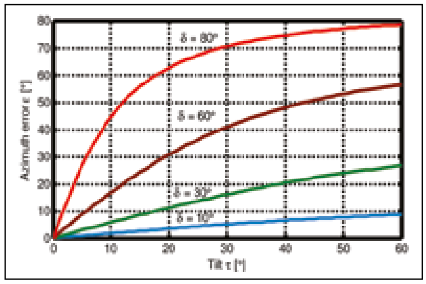

Fig. 2 Influence of tilt and inclination on azimuth

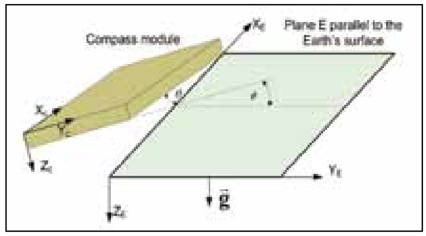

Fig. 3 Compass module orientation

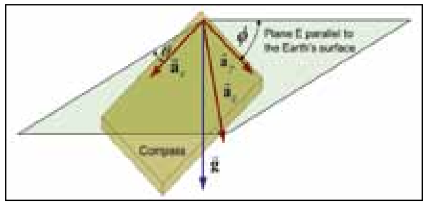

Fig. 4 Gravity components in tilted compass frame

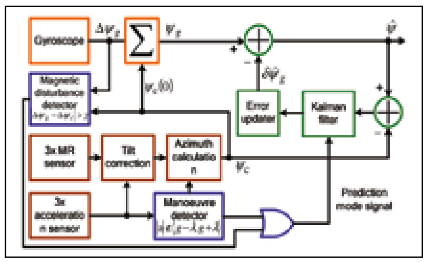

Fig. 5 Integration algorithm

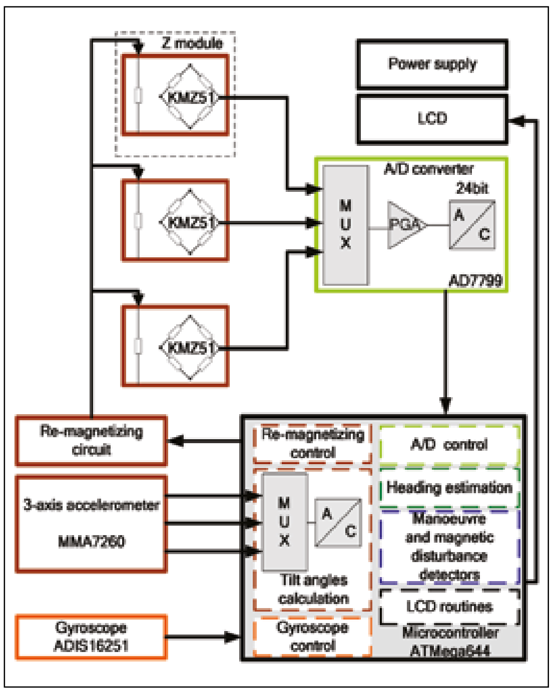

Fig. 6 Block diagram of the designed system

system [5]. There is also another simple method of correction, which assumes that the overall effect of deflections can be compensated by multiplying angular velocity measurements from gyro by a constant coefficient, greater than one [5].

Data fusion

The Heading Reference System uses the gyroscope data and the compass data to determine current heading [4, 5, 6]. The design utilizes a Kalman filter (KF) [6] to integrate the measurement data and estimate gyroscope errors. The results of estimation are subsequently used to calculate the estimated heading $\hat{\psi}$. The block diagram of the implemented integration algorithm is shown in Fig. 5.

The compass heading ψ_c is used by the Kalman filter only if it has been previously properly compensated for tilt effects. A manoeuvre detector is used to prevent the use of compass heading during acceleration when the tilt compensation is not reliable. If the total acceleration differs from 1g by more than a threshold λ, the KF switches to the prediction mode and does not perform the measurement update.

The algorithm also checks if the change of the compass heading $\Delta\psi_c$ and gyroscope heading $\Delta\psi_g$ is consistent. If these two values are not similar, the algorithm assumes that there is a magnetic field disturbance and switches the Kalman filter to the prediction mode.

These two procedures allow to eliminate invalid compass data from the filter input.

Data fusion in the described system is achieved by the means of a Kalman filter. The KF estimates residual gyroscope heading errors and provides them to the input of the error updater. The error updater accumulates them and calculates the total estimated heading error $\delta\hat{\psi}_g$, which is then subtracted from the gyro heading ψ_g, providing estimated heading $\hat{\psi}$. The Kalman filter for the designed system is based on a discrete HRS model [6], which is composed of a difference equation of dynamics (8) and an equation of observation (9):

$$\mathbf{x}(k+1)= \mathbf{\Phi}(k+1,k)\mathrm{x}(k)+\mathbf{w}(\mathrm{k})-\delta\hat{\mathbf{x}}(\mathrm{k}) \quad (8)$$

$$\mathbf{z}(k)= \mathbf{H}(k)\mathrm{x}(k)+\mathbf{v}(\mathrm{k}) \quad (9)$$

The state vector $\boldsymbol{x}$ which is estimated by the filter, consists of gyro heading error $\delta\psi_g$, gyro scale error δk and gyro bias b [6]:

$$\mathrm{x} = [\delta\psi_g \ \delta k \ b]^T \quad (10)$$

The transition matrix $\mathbf{\Phi}$ which describes the transition between the previous $\mathbf{x}(k\text{-}1)$ and current state $\mathbf{x}(k)$ vector is given as:

$$\mathbf{\Phi} = \begin{bmatrix} 1 & \Delta\psi_g & T \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (11)$$

The symbol $\Delta\psi_g$ represents a change of heading between times kT and $(k\text{-}1)T$, as reported by gyro. Taking into consideration the formulae (8) the model of dynamics can be described as:

$$\mathbf{x}(k+1) = \mathbf{\Phi}(k+1,k)\cdot\mathbf{x}(k) + \mathbf{w}(k) - \begin{bmatrix}\delta\hat{\psi}_g(k)\\ 0\\ 0\end{bmatrix} \quad (12)$$

Where **w** is the vector of random process disturbances and $\delta\hat{\psi}_g$ is the total error of gyro heading. The input of KF in the HRS system is the difference between the corrected gyro heading and the heading $\hat{\psi} = \psi_g - \delta\hat{\psi}_g$ measured by the electronic compass ψ_c. Considering the correcting term $\delta\hat{\psi}_g$ as a deterministic input signal, it can be assumed that it represents a part of the model of dynamics. Thus, the observation model (9) is given by the following equation:

$$z = \psi_g - \psi_c = (\psi + \delta\hat{\psi}_g) - (\psi + v_c) \quad (13)$$

$$z = \delta\psi_g - v_c = \begin{bmatrix}1 & 0 & 0\end{bmatrix}\cdot\begin{bmatrix}\delta\psi_g\\ \delta k\\ b\end{bmatrix} - v_c \quad (14)$$

Where v_c are measurement errors of the electronic compass and ψ is the true value of heading. More detailed description of the data fusion algorithm can be found in other authors' article [7].

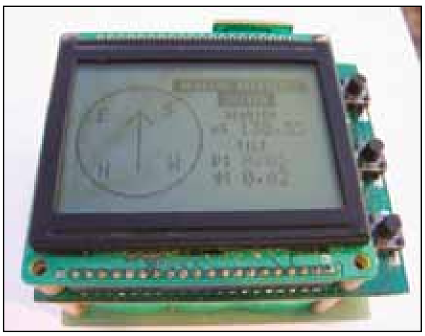

Fig. 7 Hardware part of HRS

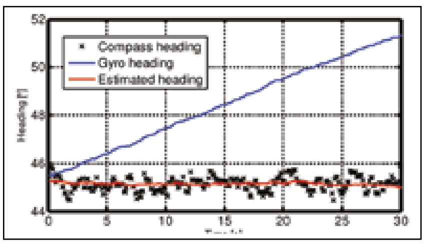

Fig. 8 Headings from gyro, compass and HRS

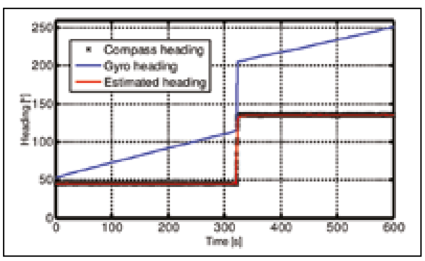

Fig. 9 Headings from gyro, compass and HRS

HRS hardware implementation

During the research work, a hardware implementation of the described Heading Reference System has been developed. The main task of the system is to determine the current heading on the almost continuous basis and with possibly high accuracy. It was assumed that the system should consist of low cost elements, have small dimensions, and battery supply. The block diagram of the prototype is shown in Fig. 6.

The HRS is controlled by an Atmel AVR microcontroller which performs initialization, measurement and calibration routines and executes integration algorithm.

Magnetoresistive sensors were used for magnetic field measurements. Tilt compensation procedure uses data from 3-axis MEMS accelerometer. Included gyroscope sensor is a fully autonomous device. It is able to measure angular rate and determine angle change.

The estimated heading is displayed on a graphical LCD module with additional information such as pitch and roll angles, current mode of filter operation (only prediction or normal work) and information about detected magnetic field disturbances and manoeuvres. Fig. 7 shows the hardware of the designed Heading Reference System.

HRS evaluation and conclusions

Observations of gyro heading, compass heading and estimated heading were carried out during evaluation of HRS performance. Fig. 8 shows measurement results for stationary HRS, aligned with ca. 45 degrees azimuth. The results shown in Fig. 9 have been observed for HRS pointing 45° through the first 320s and next rotated by 90°.

Simple statistics for the stationary period of time for the second testing scenario (Fig. 9) have been shown in Table 1.

Table 1 Statistics of heading errors.

	Compass	HRS
Standard deviation [deg]	0.318	0.136
Angle error range [deg]	2.08	0.74

As can be seen in Figs. 8-9, the gyro heading tends to almost linearly increase because of cumulative gyro errors. The compass heading has long term stability, but it is noisy. The implemented integration algorithm enables estimation of heading, taking into account short term gyro accuracy and long term compass stability. As a result fast response of the system has been preserved and noise of the compass heading have been significantly reduced.

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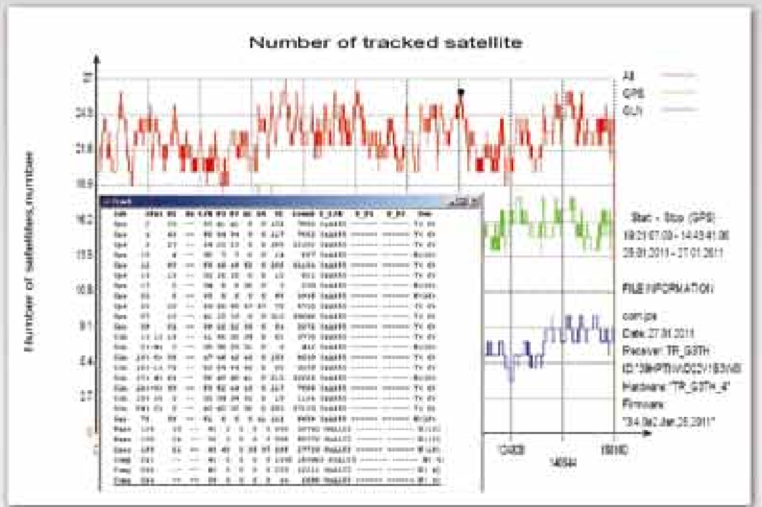
JAVAD GNSS receivers can track

With modified firmware, all JAVAD GNSS receivers can track Chinese COMPASS B1 signal now. This is 6th GNSS system supported by JAVAD GNSS (GPS, Glonass, Galileo (Giove), SBAS (WAAS, EGNOS), QZSS, COMPASS). Log file, collected on TR_G3TH board in Moscow during weekend, reported up to 26 (!) satellites locked simultaneously see picture below.

Among them:

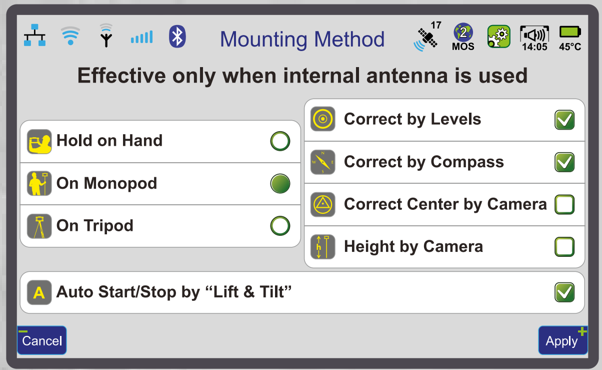
11 GPS satellites
with C/A, P1, P2, L2C, L5;
8 Glonass satellites
with C/A, P1, P2, L2C;
1 Galileo (Giove) satellite
with E1, E5A;
2 SBAS (EGNOS) satellite
with C/A;
1 QZSS satellite
with C/A, SAIF, L2C, L5, L1C
3 Compass satellites with B1.



Compass system currently consists of 6 alive satellites, 4 of them are visible in Moscow: COMPASS-G3, COMPASS-IGSO1, COMPASS-IGSO2 and COMPASS-M1. Their day track is shown on next picture.

Lift

First, put TRIUMPH-VS in "Lift & Tilt" mode.



Then, go to the survey mark, lift TRIUMPH-VS to near vertical (better than 5 degrees). Survey will start automatically and sensors continuously compensate for leveling offsets. Audio tones keep you informed of the survey progress. You can use a headset if you are in noisy area. You can also take notes by talking to TRIUMPH-VS.

Patents pending

Tilt

When you are happy with the survey result, just tilt the TRIUMPH-VS (more than 15°) and walk to the next point. TRIUMPH-VS will close files automatically.

Patents pending

Lift

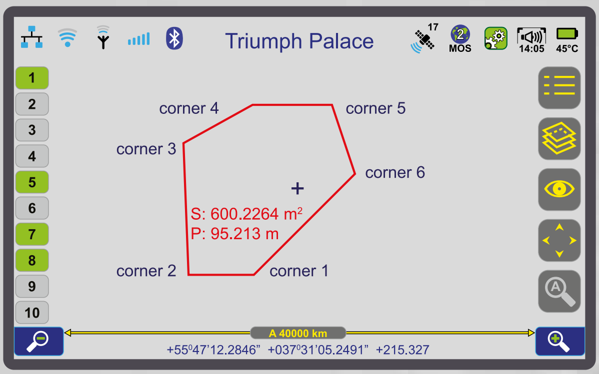
Then go to your next point. Lift it up and do again as you did in the previous survey point: Do Nothing! Just lift it up to near vertical.

Patents pending

Tilt

When you are happy again, tilt it again, and walk to the next point. Points and file names will auto-increment. You can over-write names if you like.

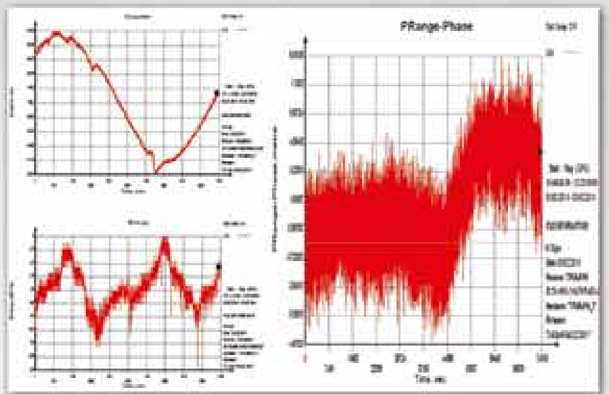
If you are doing a parcel survey (for example) after the last parcel point, push “Parcel End” and see the parcel map, parcel area and parcel perimeter instantly.

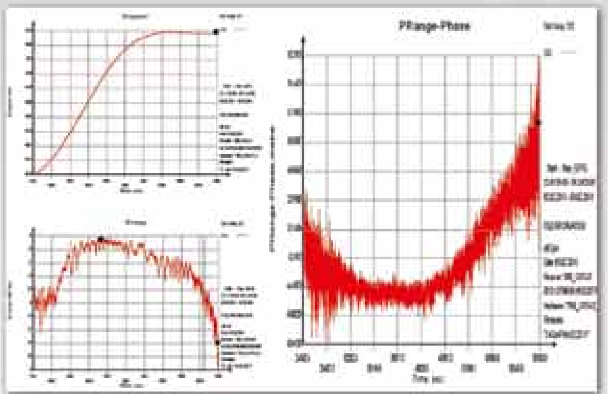


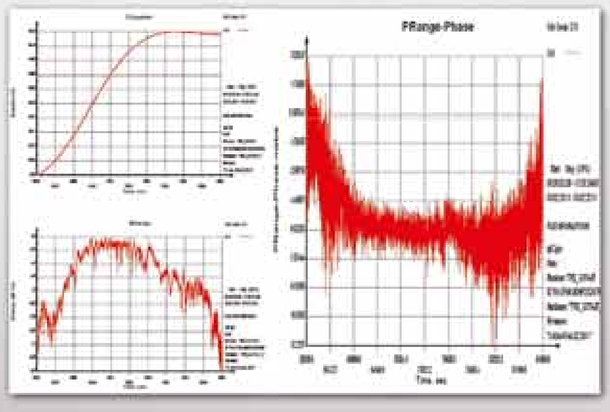
Patents pending

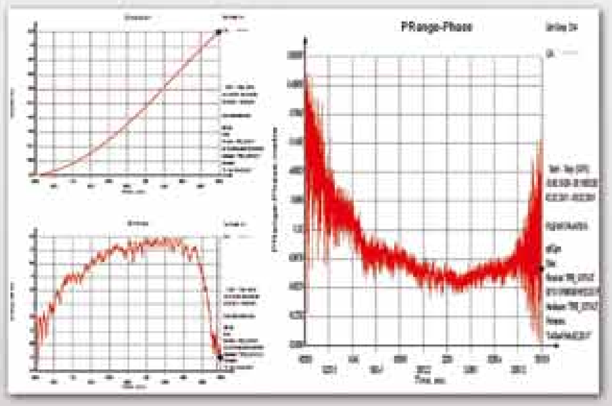
Chinese Compass (Beidou-2)

Below are Doppler, SNR and “code-minus-phase” graphs for all these satellites (G3=211, IGSO1=212, IGSO2=213, M1=214), collected during their pass:









JAVAD GNSS will add COMPASS tracking to almost all receivers in near future (firmware upgrade).

Our history

TRIUMPH-VS

GNSS Spectrum Analyzer in **TRIUMPH-VS**

Also first with GLONASS, Galileo, QZSS

And we keep working harder! Javad Ashjaee

"We have kept pace with the emergent technology"

says Vice Admiral B R Rao AVSM, NM, VSM, Chief Hydrographer to the Government of India

Would you like to highlight some of the initiatives taken by NHO in last five years?

The Indian Naval Hydrographic Department, with its rich traditions in the field of hydrography, wide ranging experience, a good infrastructure coupled with an excellent Human Resource, has the entire requisite wherewithal to be ranked amongst the best in the world. This has not happened overnight; the initial foundations have been laid by our predecessors and we who man and run the department now have been blessed by a good beginning. In the last five years, we have only added on to its already established stature.

Today with the world moving into the digital era, we have in right earnest made a good beginning to produce Electronic Navigation Charts (ENCs) for the entire Indian waters for its use in the type approved Electronic Chart Display and Information System (ECDIS). The soon to be commissioned Hydrographic Production Database (HPD) will result in all data in a seamless database, providing for simultaneous data processing and work flow by multiple-users as also bring in the improved efficiency in maintaining source data and the production .of multiple marine products, including the ENCs and Paper Charts from a single database. This arrangement will also provide for Print on Demand facility whereby any chart can be printed with up to date data incorporated, from any remote location connected to this database through the latest digital communication setup.
Our ships and survey units have been provided with the state-of-art technology available in the field of hydrography. These have been constantly replaced by the current technology as and when they are rendered obsolete. Consequently the throughputs from our ships and units have improved substantially.

The National Institute of Hydrography, Goa, an important resource centre of the Department, has been provided the required fillip to further augment the training infrastructure keeping in tune with its international stature of being a Regional Training Centre for Hydrography for this part of the globe. With its excellent Training Infrastructure and an experienced and dedicated staff, the Institute has attracted many international students from lOR and beyond. IHO, through its capacity building programmes as well as IOC of UNESCO, have been regularly subscribing for the various programmes that we conduct. We have also conducted many tailor made courses not only for our national agencies but also for international bodies. All our programmes are over subscribed and this alone speaks of the quality of training that's imparted at our Institute.

Considering the stature of the Indian Naval Hydrographic Department it was only apt that we play a leading role in this region in so far as hydrography is concerned. INHD's inherent strengths, place it in a unique position to offer hydrographic assistance to developing maritime nations of the Indian Ocean Littoral region, wherein hydrography is still in nascent state. Our Government has evinced a keen interest in the affairs of the Department and have entrusted us with the responsibility to promote hydrography in this region. We have been providing assistance in hydrography to most of our friendly neighbours through an MOU in tune with the policies of our Government. We have reached far and wide and our contributions have been much appreciated by the countries concerned as also acknowledged by the IHO. Cooperation in hydrography is increasingly seen as an important instrument of foreign diplomacy. Our men have been excellent ambassadors of our country through these processes.

Soon our survey fleet will have an addition of six catamaran hull medium size survey vessels with the state-of-art technology. This was warranted considering the extra workload owing to the increase in trade and opening of new ports as also because of the growing requirement of defence surveys of our Navy. These vessels are in advanced stages of construction and soon will join our survey fleet. Our proposal for a survey training ship has been recently cleared and accepted by the Government. The required administrative formalities will be undertaken for its construction in a phased manner. Considering the increasing requirements of survey of Andaman and Nicobar Islands Command, we have setup a Hydrographic Survey Unit which will look after some pressing requirements of Port Blair harbour and neighbouring islands.

What kind of surveys NHO generally undertakes?

NHO generally undertakes following types of surveys:

- Navigational Survey
- Oceanographic Survey
- Defence Related Survey
- Surveys as required for Maritime Boundary Delineation
- Pipeline &Cable Routing Surveys
- Offshore Development Surveys
- Surveys for Continental Shelf
- Surveys for Coastal Zone Management (CZM)

How have technologies like GPS and GIS, impacted the activities of National Hydrographic Office in last few years?

GPS technology has been used by the Indian Naval Hydrographic Department for more than 20 years. We have kept pace with the emergent technology in this field. Our ships use Differential GPS (DGPS) for positioning the vessel, whilst undertaking hydrographic surveys. Increasingly, the traditional methods of extension of control over land have changed to the satellite derived methods and we have the state-of-art geodetic GPS equipment and system/software in our inventory. We have now moved over from DGPS to DGPS RTK. These techniques are used in our ships today to derive the best from the improved 3D position accuracy they provide. We are experimenting with the varied options that provides RTK tides and soon we will have SOPs in place to make this a common approach for survey. We have also made a beginning moving over to the Satellite-based Augmentation System (SBAS) of differential GPS (DGPS). We are eagerly waiting for our own SBAS in GAGAN. Marine charts including ENCs have moved over to WGS 84 Datum world over. This automatically pre-empts the use of GPS. The GPS, in all its avatars, find increasing use for hydrographic applications. The digital charts in its official standardised form come as ENCs for use in ECDIS.

The standards of ENCs have been recently fine tuned to be accepted with GIS technology. The ENCs have the potential to form the backbone of a marine GIS. GIS is as important to the Hydrographer as it is to any mapping agency. However, many aspects and its true potential are yet to be fully tapped. Our hydrographic office is soon to have a new Hydrographic Production Database. The GIS used is CARIS based which is a typical

GIS for marine application. Like I mentioned before, this will result in availability of all data in a seamless database, providing for simultaneous

All the major survey equipment/instruments have been standardised in the department based on ease of operation, reliability, accuracy, ruggedness, IHO S-44 compliance and availability of authorised local service centers in India.

data processing and workflow by multiple-users as also bring in the improved efficiency in maintaining source data and the expeditious production of multiple marine products, including the ENCs and Paper Charts from a single database. This arrangement will also provide for Print-on-Demand facility. It will bring in greater efficiency in our work flow and will certainly improve our productivity as well as accuracy.

What role do you see for the technologies like GPS in the areas of Maritime Safety?

The Global Positioning System (GPS) has entered every sphere of our life. It has deep impact on any marine operations or applications. Today GPS is available right from a small country craft engaging in fishing to the most sophisticated vessels that ply the oceans. This is one technology that has pierced every segment of the socio economic fabric to become one of the necessities especially so in the marine world. It is important for mariner to know the vessel's position in open sea as well as in congested harbours and waterways and today I can safely say that about 99% of these mariners rely on GPS. This has proven to be most relied method for mariners to navigate, measure speed, and determine location. This has increased the levels of safety and efficiency of mariner many folds.

Capacity building is one aspect which is becoming a key issue given the pace of technology changes. What is NHO's strategy in this regard?

All the major survey equipment/ instruments have been standardised in the department based on ease of operation, reliability, accuracy, ruggedness, IHO S-44 compliance and availability of authorised local service centers in India. It has been our endeavor to upgrade the survey equipment to the latest technology in market when due for replacement by means of a long term procurement plan. We make every effort to make available the latest technology for ensuring stringent data quality and also for improved productivity. National Institute of Hydrography, our premier training organisation, is constantly provided with the latest technology for training and the best professionals man this training set up to ensure the throughputs are of desired quality. We have a well calibrated three tier system for training for both officers and sailors. Besides we do organise workshops and adhoc training capsules as and when we induct new technology where in OEM Engineers are also called to deliver lectures. During these interactions, our trainers are well exposed to further train others. These adhoc training capsules are also conducted with OEM's involvement on all occasions when any fresh batch of equipment/ system is commissioned. Further, regular seminars are also conducted so that good exchange of ideas and views take place for the betterment of all. We also take the opportunity to participate in seminars and conferences conducted elsewhere to derive the most from it. Continuity training on board ships is another aspect by which our men are constantly updated on current technology. We believe learning is a continuous process and our Human Resource is given a conducive environment and ample opportunity for self advancement. All this has helped the department to keep pace with technology

Does NHO offer its services to other countries also?

We have been quite active in pursuing hydrographic cooperation in the IOR. We already have an MOU with Mauritius where-in we are providing hydrographic assistance. We are undertaking surveys of their important ports and water-ways once a year and producing nautical charts of the areas surveyed. We are providing training to their personnel at NIH, Goa as also provide on job training when our ships survey their waters. We are also providing technical assistance in setting up of hydrographic infrastructure. This MOU was initially for a period for 5 years which has recently been extended by another 5 years. We are also providing similar kind of assistance to Seychelles and Maldives. Sri Lanka too benefits a lot from INHD and the assistance we provide from time to time. Of late Myanmar, Muzambique and Saudi Arabia have expressed their desire for our assistance in the field of hydrography. South Africa and the South Africa Islands Hydrographic Commission have evinced keen interest in availing our training facilities. This is likely to move into a bigger hydrographic cooperation with these regions and talks are on anvil. The Department is also actively involved in Co-operative Mechanism on Safety of Navigation and Environmental Protection in the Straits of Malacca and Singapore wherein India has committed and provided funds, training and technical expertise for two projects. You can see the current engagement and reach of the department in so far as pursuing hydrographic cooperation in IOR and around. Besides all this, our Training facilities are much sought after in IOR and beyond and all our training programme at NIH, Goa are generally oversubscribed giving a good indication of the excellent quality of training we provide.

SDI framework

The work of building "Spatial Data Infrastructure" (SDI) is in progress all over the world. There are many challenges: governance, organisational, technical, data sharing, transitional and more. Readers may recall that in Feb 2011 issue we have carried the first part of the paper. Here we present the concluding part.

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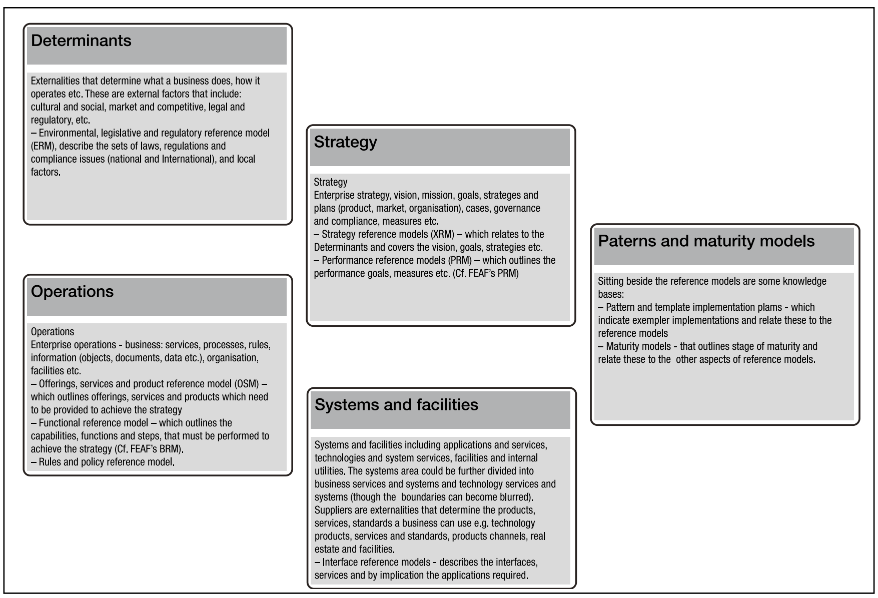
Scope of an SDI framework

Best practice implementations need to reflect experience: with cost effective world leading operational national systems; several generations of change i.e. experience with different models of private sector and public sector collaboration; in creating and extending systems of policy, regulation and governance; of the affects of different governance regimes, cultures and from international programmes. They therefore need to cover:

- Principles, Patterns and Anti-patterns i.e. lessons on what has worked and what to avoid. Arising from multiple generations of systems (reflecting the economic and social development);
- Collaboration models: indicating interfaces between roles and systems (that in different situations will be private sector or public sector);
- Service and components models: which describe the core components and applicable technologies and standards;
- Standards and technologies: including links to international standards and programmes (ISO/TC211, ISO 19115, FOSS4G etc.);
- Regulatory models: based on past success in the effective systems of policy, regulation and governance in national spatial systems operational delivery. Included in this needs to be recognition of different customary and cultural structures and approaches;
- Promulgation, educational and research models (explain, learn, find out): that identify the activities needed to raise awareness, and underpin new training required and provide a framework for research.



Therefore we propose a set of reference models which capture the fundamental issues

SDI Determinants

Legislative and regulatory reference model: describe the sets of laws, regulations and compliance issues (national and international).

Local factors reference model: describes social and cultural factors that influence strategy

NSDI strategy

Strategy reference models - which relates to the Determinants and covers the vision, goals, strategies etc.

Performance reference models - which outlines the performance goals, measures etc. (Cf. FEAF's PRM)

NSDI operations

Services and product reference model - which outlines the services, products and offerings which need to be provided to achieve the strategy

Functional reference model - which outlines the capabilities, functions and steps, that must be performed to achieve the strategy (Cf. FEAF's BRM).

Rules and policy reference model - which outlines the rules and policies that are required by the strategy and determinants and to support operations.

Information reference model - which outlines information, metadata and data required by the strategy and determinants and to support operations.

Organisational reference models - which outlines the organisational units, roles, techniques, skills that are required by the strategy and determinants and to support operations.

NSDI systems and facilities

Interface reference models - describes the interfaces, services and by implication the applications required for NSDI to operate.

Technical reference models - describes the technologies, standards required to supports the interfaces.

Vendor reference model - describes the products, agreements etc. required

NSDI patterns and maturity models

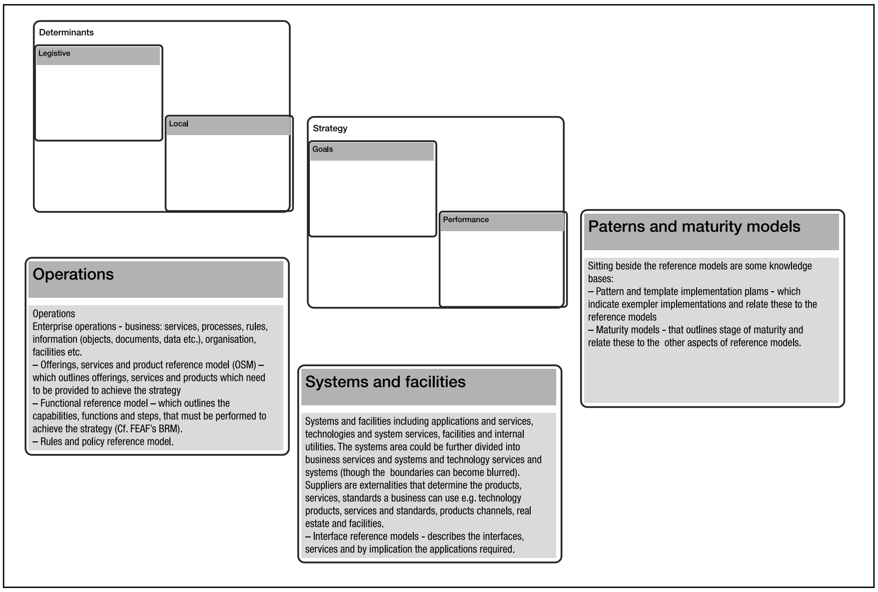
Sitting beside the reference models are some knowledge bases:

Patterns and template implementation plans - which indicate exemplar implementations and relate these to the reference models

Maturity models - that outlines stage of maturity and relate these to the other aspects of reference models.

These reference models are related to allow referential and inferential analysis to be performed. The first three can be considered to represent the requirements and the last two are in the solution domain.

Key characteristics of the SDI framework proposed



We can see a number of other key characteristics we require

- Implementation technology neutral and non-aligned - our NSDI must intrinsically technology and vendor neutral i.e. having no affiliation of alignment, and no preferred SDI technology, products. This allows a clearer focus on the real needs and on standards.

- Accessible by anyone from anywhere - this effectively means Web accessible and is key so that knowledge can accessed where, when and by whom its it required and that knowledge can be capture as a natural by product of field work.

- Supporting different roles, scenarios of use, and levels of control - that is with role based access and presentation, so that people can see what they are interested in in a way that makes sense to them and can change information that is in their domain of control.

- Ensure semantic precision - which ensures it may be analysed with efficiency, fully auditable, that the basis of decisions is explicit, objective and transparent. The lack semantic precision is one of the key problems with most documents.

- Represent idealised models of NSDI - that has a holistic, coherent and complete set of well-structured, unambiguous and well partitioned and categorised set of business definitions (roles, functions, interfaces etc.). Has an explicit conceptual model of how the NSDI organisations are structured and operate (e.g. reporting, controls, data flows etc.)

- Divides the generic framework from the country specific implementation - so the generic framework is reusable and extensible. Allows nations to maintain their know how i.e. how they do things, why they do things - rather than this knowledge be in the hands of third parties with vested interests e.g. consultants, vendors.

- Allows relationships and concepts to be - visualised, analysed and reported on (in SDI we all know that a visualisation can tell convey information in a powerful way).

- As simple as possible - to reduce complexity we limit connections within each level and between each touching levels.

Roles boundaries and flows

Natural Boundaries around Responsibilities

An operationally effective NSDI is contributed to by meeting the key challenges in developing an inclusive model of governance and effective data sharing. Our themes are that public and private certainly share the task of establishing efficient, operational NSDI and new governance mechanisms are needed to get us there.

The boundaries around the responsibilities need to be drawn and re-drawn. Reorganised government agencies are necessary and relatively simple, being ultimately single legal entities, but sufficient change also requires private sector engagement. So the reorganisation of responsibility is not so simple.

The Spatially Enabled Government in Victoria Australia including [SEG,2007] and the work of the Australian Office of Spatial Data Management (OSDM) suggests "there is general acknowledgement that the major challenges in implementing an enabling platform are not technical, but institutional, legal and administrative in nature."

They [SEG, 2007] identifies three strategic challenges: governance, data sharing and access and an overarching challenge regarding how to develop a SDI that will provide an enabling platform in a transparent manner that will serve the majority of society. It also suggest SDI development has often been "dominated by the concerns of central governments usually without the participation of stakeholders from the sub national levels of government, the private sector and academia" and oriented at "professional elite rather the population as a whole who are the main beneficiaries". They suggest an SDI includes "enabling platform linking those who produce, provide and add value to data".

SEG reference many aspects of an NSDI: organisations, roles and relationships; data, technology and standards; processes, actions and practices; policies and decisions; criteria, business goals, strategies, products and services, laws and regulations.

We see our work building upon past results by facilitating the strategic challenges related to inclusive models of governance for NSDI establishment. What we propose is both a renewed focus on the definition of the responsibility boundaries and a supporting framework to articulate, visualise and analyse the information and knowledge flows.

SEG suggested that "a new business paradigm [promoting] the partnership of spatial information organisations (public/private) to provide access to a wider scope of data and services, of size and complexity that is beyond their individual capacity." There are recognitions in the SEG work also that we need something above the detail instance and implementation specific data that we commonly find referred to by technical specialists.

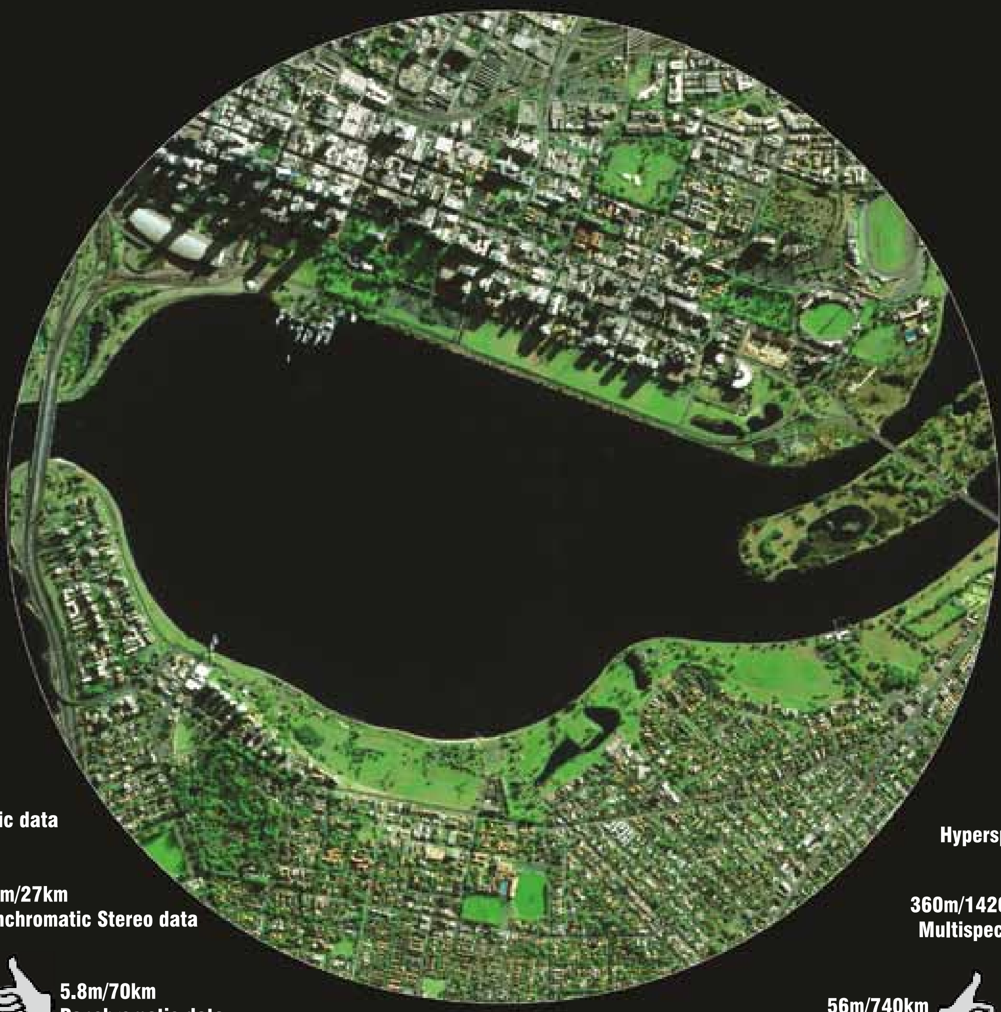
Public and private roles

When considering an NSDI we have to balance two opposing flows i.e.of control and of data

- Top to bottom - control and governance naturally flows from top to bottom
- Bottom to top - data naturally flows from bottom to top.

Our implementation mediates between these flows. The state plays a pivotal role in the sound initial establishment of new key national infrastructures e.g. post, telephony, power, broadcasting, road and rail. As approaches to national

Indian Remote Sensing Satellites (IRS) offering a bouquet of data services



Perth Australia as seen by IRS

1m/9.6km
Panchromatic data

2.5m/27km
Panchromatic Stereo data

5.8m/70km
Panchromatic data

5.8m/23km
Multispectral data

23m/140km
Mulstispectral data

36m/140km
Mulstispectral data

56m/740km
Mulstispectral data

360m/1420km
Multispectral

64 channel
Hyperspectral data

"Globally distributed through a network of 20 international ground stations and 20 resellers".

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developments mature we see individuals, the state and private sectors organisations increasingly share these roles and responsibilities (as we have in the other areas of national infrastructure). NSDI is a new class of 'data' infrastructure. It enables efficient economies and supports the nation's socio-economic development objectives and policies.

The challenge for many years, including those when paper based maps, plans, designs and specialised dedicated models suited to a single audience or purpose were common, has been to integrate, maintain, analyse, and enable access by a wide range of different parties.

Individuals, state and private sector organisations share the mandate and responsibility for their establishment and operation. The framework proposed provides a means for dealing with the information about these things (meta-information) that enable governance. SEG suggests a broad goal for an NSDI is to support "more effective and more transparent coordination". The framework approach here, in the first place allows an effective and transparent co-ordination of the meta-information so that the professional elite and all other stakeholders are able to participate. In this way the framework relates to the flexible setting of public/private responsibility boundaries.

The implementation of complex IT infrastructures (e.g. NSDI), with governance, stakeholders, business users, designers, engineers and planners is assisted by inclusive, early, persistent engagement on responsibilities. Frameworks that enable visualisation of the meta information (functions, meta-data, roles, assets, networks of related elements, …) allow the overall picture to be worked with to suit the needs of the entire constituency.

We want to be able to understand how a number of parties can collaborate in an NSDI. To map the roles, functions, assets, data etc. of these entities we need a framework which is a canonical model. If we wish to be able safely encourage the private sector to engage in some areas we need to very clearly understand the upstream and downstream implications e.g. from a function upstream to what regulations or goals it is critical to from the NSDI perspective and not merely the perspective of an implementing party. The down stream flows are to what technologies and assets are interrelated.

Such an understanding is fundamental to knowledge of gaps, overlaps, risks and impacts of a set of organisations engaging collaboratively to implement, operate and evolve an NSDI.

Engaging the private sector

In the agreements needed on responsibility boundaries a flexible approach contributes success. Agreement and definition of NSDI would be shared, state undoubtedly have the mandate for governance and private are the likely location of efficient implementation and operation.

"Government has to be a smart buyer, meaning knowing what to buy, deciding from whom to buy it, and then determining what it has bought; that is, preparing careful specifications as what is to be purchased, conducting a competitive procurement in a competitive market, and monitoring the contractor's performance." (Ref Kettl 1993)

Strong commitment from the top is needed to build the capacity for effective contracting and procurement because of the complexity and challenges of public contract management. (Ref Savas)

NSDI, being relatively new national infrastructures as well as complex systems are ideal programmes to which past lessons on responsibility setting be applied. Hernando de Soto himself illustrates this opportunity. "In many countries, years of state regulatory intervention have produced bureaucratic obstacles and economic stagnation. Hernando de Soto illustrates how much time is wasted in Peru following the labyrinthine official procedures to start a business or build a house: It takes 289 days to register an industrial enterprise and 26 months to license informal taxi operators, for example. The informal economy (i.e., 'black market') encourages far greater productivity than the official sector." (HDS Ref 1989) He advocates deregulation, de-bureaucratisation, and decentralisation.

State and private engagement is necessary for delivery of NSDI. New mechanisms for governance are required for NSDI implementations to work. Engagement between state and private sector should aim to achieve economic efficiency through exposure to market discipline. The emergence of demand-driven, market-based arrangements can be sued to satisfy new needs associated with NSDI.

While privatisation can indeed be mismanaged in these ways, management of ordinary public services suffers from many of these same shortcomings; that is, poor management can sometimes be found whether government is managing public employees or the privatisation process. When mismanagement occurs in the private sector, market forces tend to weed it out ruthlessly. Privatisation and public-private partnerships reflect market principles and together constitute a strategy for improving public management.

Conclusions

We seek to make a non-incremental step in the way that NSDIs are implemented.

We believe that an NSDI requires a framework with specific characteristics, capabilities and structure in order to allow best practice to be capture and applied. It is only by establishing this that we will significantly affect the efficacy of NSDI implementations. Assuring implementation schedules, operational effectiveness and fit for purpose.

Many best practice methods have been identified that we can learn from and we believe there are better ways now available to implement a framework to assure NSDIs to operate effectively.

At present many parties are focused on capturing knowledge that should reside in such a framework. Sadly much of the knowledge still resides in documents or in people's heads where it is not particularly useful in regard to accessibility, capacity to be integrated and analysed.

Individuals, state and private sector organisations share the mandate and responsibility for NSDI establishment and operation. The strategic challenges related to the inclusiveness of the governance models and inherent approaches to data access, renewal and use.

What we propose is both a renewed focus on the definition of the responsibilities associated with NSDI establishment and a supporting framework to articulate, visualise and analyse the information and knowledge flows.

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UN proposes global geospatial information mechanism

"There is general agreement of an urgent need for an inter-government consultative mechanism that can play a leadership role in setting the agenda for the development of global geospatial information, and to promote its use to address key global challenges; to liaise and coordinate among member states, and between member states and international organizations," according to a statement by the United Nations (UN). During a meeting on Global Geospatial Information Management (GGIM), Co-chair Hiroshi Murakami said while there are various international organisations that have been working on geospatial information, the UN feels that there is a need for an official mechanism that would link the outcomes of such organisations to specific policy decisions and actions of member states. *www.futuregov.asia*

US appoints 15 geospatial advisors

The US Secretary of the Interior Ken Salazar appointed 15 individuals to serve as members of the National Geospatial Advisory Committee (NGAC) for 3 years. They are Dick Clark, State of Montana; Jack Dangermond, ESRI; Dr. Jerry Johnston, US Environmental Protection Agency; Anne Hale Miglarese, Booz Allen Hamilton; and Matt O'Connell, GeoEye ; Joanne Irene Gabrynowicz, University of Mississippi; Laurie Kurilla, Ventura County, CA; Dr. E. Donald McKay, State of Illinois; Dr. Timothy Nyerges, University of Washington; Pat Olson, Aero-Metric, Inc.; Mark Reichardt, Open Geospatial Consortium; Anthony Spicci, State of Missouri; Gary Thompson, State of North Carolina; Gene Trobia, State of Arizona; and David Wyatt, Eastern Band of Cherokee Indians. *www.doi.gov*

USDA unveils rural mapping Atlas

The US Department of Agriculture (USDA) is giving citizens a new way to access a host of county-level data. The Atlas of Rural and Small-Town America is an online mapping tool that captures more than 60 statistical indicators encompassing demographic, economic and agricultural data from across the U.S. By releasing the county-level data, the USDA hopes to spur additional economic development. *http://iowaindependent.com*

Israel weighing Street View benefits despite security concerns

While Google's Street View map service has sparked privacy debates around the globe, in Israel, government officials are worried that the service could endanger public figures by giving terrorists detailed information that could be used in carrying out attacks. Israel is weighing whether to allow Google to photograph Israeli cities to promote tourist sites despite risks to privacy and safety. *www.latimes.com*

Karnataka to map government schools

The Sarva Shiksha Abhiyan (SSA) in Indian State of Karnataka will use GIS to map about 74,000 government schools in the state. The project also includes a web-based application for accessing the district information system of schools education (DISE) database and the integrated database of schools. *DNA India*

Ground mapping for Chinese Army

People's Liberation Army (PLA), China, got a new digital ground mapping information system to make battlefield visible and transparent. The system is made up of several mobile shelters including mapping, environmental simulation and satellite positioning. It can display not only 3-D geographic information, but real-time track. It can also display the dynamic positions of the troops and main battle equipment. *www.defpro.com*

Mapping telecom dept's land assets

The Indian telecom department will soon start mapping of the land assets directly under its custody and those transferred to its constituents like Bharat Sanchar Nigam Ltd (BSNL), Mahanagar Telephone Nigam Ltd (MTNL), Telecom Consultants India Ltd (TCIL) and ITI Ltd. This mapping of the department's land assets will also include the government land holdings in Tata Communications and details of all commercial premises, heritage buildings and land belonging to the telecom department that is disputed or encroached. *Economic Times*

Road maintenance in Assam, India

Indian State of Assam is planning to set up a GIS-based road asset management system by 2012 to streamline the maintenance of road network in the state. The state government will have to incorporate the system as part of its plan to improve nearly 800 km of state roads to obtain the USD 200 million loan from the World Bank. *www.telegraphindia.com*

Digital maps in census in Bangladesh

Bangladesh's Planning Minister AK Khandker has said that digital maps for each and every moujas (an administrative unit) and areas have been prepared for the first time through aerial photography to bring accuracy in the upcoming Population and Housing Census-2011 to be held next month. The Planning Minister said that all the necessary preparations have been taken this time to successfully hold the census overcoming the shortcomings of the previous censuses. This will be the 5th census in the country after the last census was held in 2001. *www.unpan.org*

Delhi Metro's airport corridor mapped on GIS

The Delhi Metro's showcase Airport Express Corridor, connecting the Indira Gandhi International Airport to the heart of the city, was rolled out for the public recently. This will be the first line in the country to be mapped on GIS to enhance safety, maintenance and traffic regulation. Delhi Airport Metro Express Private Limited, the company operating the line, has mapped all the emergency services, including fire stations, police stations, hospitals etc along the alignment. *www.thehindu.com*

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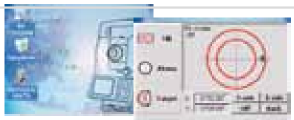
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PRS92 surveying standard compulsory

All offices of Department of Environment and Natural Resources (DENR) in the Philippines have to adopt the Philippine Reference System of 1992 (PRS92) as the standard reference for all their surveying and mapping activities. "PRS92 is based on the World Geodetic System of 1984 (WGS84) which makes use of the GPS. Adoption of this system in the Philippines may help the country to be at par with global standards.*www.zamboangatoday.ph*

Russia loses and then finds GEO-IK-2

Russia restored contact with a military satellite, GEO-IK-2. The satellite went missing the day before, after entering into the wrong orbit. It has been designed to create a detailed 3-D map of the Earth and help the Russian military to locate the precise positions of various targets. The Russian Defense Ministry has set up a joint commission with Russia's space agency Roscosmos to investigate the possible causes of the incident and to attempt bringing the satellite to the designated orbit. *RIA Novosti*

Russia, India collaborate on GLONASS

India has long been famous for its highly qualified engineers and programmers. It is natural that Russia's federal operator of Glonass, the NIS company, is strongly interested in India's market. At the same time, Indian innovative achievements can also come in handy in Russia, the deputy head of the NIS company Vladimir Vozhzhov said in an interview with the Voice of Russia. "Last year the Russian Federal Space Agency (Roskosmos), the NIS company and India's Space Research Organization (ISRO) signed a MOU to establish a joint venture that would provide navigation services on Indian territory. A draft agreement has been finalized already and now is due to be considered in Delhi," Vladimir Vozhzhov said. "The joint venture will help promote Russian technology in India and launch the production of navigational equipment there not only for domestic use but for also for exports into Russia. Later this equipment will be delivered to dozens of other countries interested in operating Glonass," Vozhzhov believes.*RIA Novosti*

Contract given for navigation system

Northrop Grumman and the University of Minnesota will develop a collaborative navigation system that leverages sensor information from multiple aircraft. It will allow highly accurate navigation performance in all flight conditions, even in areas where GPS information is unavailable. The contract for the system development comes from the U.S. Air Force Research Laboratory for its Collaborative Robust Integrated Sensor Positioning Program. *www.upi.com*

GLONASS-K launched

The first new-generation satellite GLONASS-K reached its targeted orbit on Feb 26, 2011. It was carried into its planned orbit by a Fregat booster. The Glonass-K, which has a service life of 10 years, will transmit five navigation signals

Minister blames Russian space agency

Deputy Prime Minister Sergei Ivanov accused Russian space agency Roscosmos of failing to manufacture enough advanced spacecraft. "To a large extent, the plans have been foiled," he said. Russia made only five out of a planned 11 spacecraft last year, although the country maintained the global lead in the number of space launches, totaling 31 in 2010. He also confirmed that the loss of three Glonass satellites last year cost Russia 2.5 billion rubles ($86 million) in direct damage. *RIA Novosti*

Senator to introduce privacy bill for LBS

The US needs consistent rules for how law enforcement agencies can access the ever-growing collection of location-based data from mobile devices, according to a US senator Ron Wyden, an Oregon Democrat. He said that he will soon introduce a bill that would require law enforcement agencies to get court-ordered warrants to get location-based information from smartphones and other mobile devices, instead of simple subpoenas or other methods without court oversight. The increasing ability of mobile service providers to track customer locations raises "serious issues" for law enforcement and intelligence agencies, he added. *www.pcworld.com*

Navigation aid for Manila residents

The Asiatype Group of Companies introduced its first locally made GPS PND, Vector V100. It employs electronic maps, route plotting and rerouting and turn-by-turn voice directions. It also features 38,000 points of interest *www.technologyinquirer.net*

GPS for local trains in India

According to a Railway Board official, the Research Design and Standard Organisation (RDSO) has started trial of the new device on the pattern of Delhi Metro trains. If it is successful, the railways would implement it on priority basis in local trains across the country. According to RDSO director, railways have been consulting several other agencies which are competent in designing and developing such a device. *.www.timesofindia.com*

FORM IV

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I, Sanjay Malaviya, hereby declare that the particulars given above are true to the best of my knowledge and belief.

March 1, 2011 Signature of publisher

Navteq to get Bing power on Nokia

Nokia and Microsoft has announced new partnership. Now onwards, Nokia Maps would be a core part of Microsoft's mapping services. For example, Maps would be integrated with Microsoft's Bing search engine and adCenter advertising platform .*www.microsoft.com*

ROUTE 66 new app for Android

ROUTE 66 mobile app, ROUTE 66 Maps + Navigation relies on TomTom's maps and location content to deliver navigation solution for both drivers and pedestrians around the globe. Aside from "classic" features found in pretty much any decent navigation app out there the new app also comes with optional live-services like Real Time Traffic and Speed Camera. *www.intomobile.com*

MTS to sell Russian phone with Glonass

OAO Mobile TeleSystems plans in April to start selling Russia's first smart phones equipped with the Glonass navigation network. MTS Glonass 945 will cost about 11,000 rubles ($376) and also be compatible with GPS. *www.bloomberg.net*

Hands-free navigation solution

The Magellan Premium Car Kit is compatible with the latest iPhone and iPod Touch models. The Kit includes a powerful, built-in GPS receiver that provides faster and more accurate location information to the driver's Apple iPhone and enables an iPod Touch to be used as an in-vehicle GPS device. *www.magellangps.com*

Consumer electronics devices doubled

According Berg Insight report, the worldwide number of shipped consumer electronics devices with cellular connectivity grew to 22 million in 2010 compared to 11 million in the previous year. *www.berginsight.com*

Galileo update

Galileo test environment open for business

The Galileo Test and Development Environment (GATE) in Berchtesgaden, Germany, officially opened on February 4. The system operator, IFEN GmbH of Poing, Germany, jointly with the German Federal Minister of Transport, Building and Urban Development, announced the opening for use by commercial and organizational entities seeking to test equipment with the coming Galileo signals.

GATE was developed on behalf of the German Aerospace Center (DLR) with funding by the German Federal Ministry of Economics and Technology. The test area extends across a valley of approximately 65 square kilometers, south-east of Munich, where antennae atop surrounding peaks broadcast the various Galileo signals. Technical details and specifications of the test environment are at *www.gate-testbed.com.*

Czech firms to profit from Galileo seat transfer to Prague

Czech firms will benefit from moving of the headquarters of the Galileo Supervisory Authority (GSA) to Prague, GSA head Carlo des Dorides of Italy told journalists. Czech firms may, for instance, take part in the development of signal receivers or applications for the Global Navigation Satellite System (GNSS), he said during his first day at the GSA headquarters in Prague.

Transport Minister Vit Barta said the GSA transfer to the Czech Republic may be a great advantage to maintain competitiveness. A space programme, just like nanotechnologies, is a promising area, he said. The concrete plan for the moving of 50 GSA staff from Brussels to Prague may be available in around three months, according to Barta. He said he also expected signing a host agreement during this time. *Czech News Agency (ČTK)*

ESA conducts Europe-wide Galileo satellite launch dress rehearsal

Europe's GNSS system is still six months away from first launch of its in-orbit validation (IOV) spacecraft, but one Galileo satellite has already been put through its paces, taking center stage in a Europe-wide exercise conducted recently by the European Space Agency (ESA).

The satellite in question never left the confines of its Thales Alenia Space (TAS) integration facility in Rome, Italy, but was connected to a distant trio of control centers during the nine-day System Compatibility Test Campaign (SCTC-1), which began on January 25. These same sites will oversee the satellite for real following its launch this August on a Soyuz rocket from Europe's Spaceport in French Guiana, along with a second Galileo satellite. Despite their name and test demonstration role, the IOV satellites will become part of the full operational capability (FOC) constellation of 27 satellites plus three on-orbit spares.

NovAtel announces SMART-MR15™ GNSS Receiver/ Antenna

NovAtel released its new SMART-MR15 antenna. It builds on last year's successful launch of NovAtel's SMART-MR10 GNSS receiver/ antenna. Speaking to Coordinates Mr . Ben Greenwood, Product Manager, Enclosures, NovAtel Inc. explains about the new receiver antenna

How 'smart' is SMART-MR15 from its predecessor?

The SMART-MR15 adds an embedded cellular modem and NTRIP client. The NTRIP v2.0 client has been ported from our powerful, next-generation OEM cards and the cellular modem provides 3.5G download speeds up to 7.2 Mbps.

What is the most important feature of the new antenna/receiver?

With its new 'smarts', the MR15 allows simple and seamless access to Internet delivered corrections such as state CORS systems or private RTK networks. This feature provides scalable positioning accuracy without the need to set up a local base station.

What are the different applications this smart antenna/ receiver is appropriate for?

The rugged SMART-MR15 is designed and tested to ensure continuous, reliable performance. Robust input power handling and a multitude of interface options including CAN bus, make the product ideally suited for tough on-machine environments including agriculture, construction, and mining applications.

Spirent and Bluetest collaborate

Spirent Communications and Bluetest AB have announced their collaboration to advance Over-The-Air (OTA) test methods for mobile devices. The two companies have been conducting trials and making technical contributions to industry standards groups. By combining Bluetest's expertise in reverberation technology with Spirent's expertise in wireless channel emulation and GNSS testing, the companies plan to greatly improve test methods for characterizing MIMO and GPS OTA performance of mobile devices. Automated test solutions based on these advancements will characterize device performance in a fraction of the time spent using alternative approaches. *www.spirent.com*

Compact GPS Compass products

Hemisphere GPS has released two very compact GPS compass products; the V102™ all-in-one and the H102™ OEM module. These products are ideal where heading and positioning are needed for marine and land-based applications such as yacht navigation, auto-pilot and machine guidance for earthmoving machinery. V102 is the market's smallest, single-enclosure GPS compass and positioning system, while the H102 OEM board, found in the V102, is the market's smallest fully integrated single board GPS compass that provides a low-cost yet highly accurate solution for integrators. *www.hemispheregps.com*

Leica's SaaS with automatic reporting

Leica GeoMoS Web now comes with a new automatic reporting tool, in addition to many options for analysing and visualising monitoring data and other new functionalities that make it even more flexible. Each authorised user can access their monitoring project anywhere, anytime. It is a SaaS (Software as a Service), an on-demand service that uses a Web-based application to display monitoring data. It supports highly secure https and SSL encryption for secure data transfer. *www.leica-geosystems.com*

GeoCore 2.0

Blue Marble Geographics has released GeoCore 2.0, the all-in-one data conversion developer tool kit for geospatial data. It includes the latest versions of GeoTransform, GeoCalc, and GeoTranslate software development toolkits. Users can now seamlessly work with any Blue Marble data conversion toolkits in the same development environment to build powerful geospatial software. *www.bluemarblegeo.com*

GeoExplorer 6000 series

Trimble GeoExplorer® 6000 series of is a high-accuracy GNSS handheld computers. The series delivers dramatic improvements in difficult GNSS environments such as urban canyons and under tree canopy using Trimble® Floodlight™ satellite shadow reduction technology. The handhelds includes a dual-frequency GPS and GLONASS receiver and antenna, 5-megapixel camera and 3.5G data modem. Its large sunlight-readable display, field-swappable battery, and powerful processor are designed to meet the daily challenges of the most demanding GIS workflows. *www.trimble.com*

u-blox and Rohde & Schwarz team up

u-blox and Rohde & Schwarz (R&S) have successfully concluded a simulation of GALILEO. The test, carried out with the R&S SMBV100A vector signal generator and its GNSS simulation options, verified the u-blox proof-of-concept and the compatibility of its receiver technology with the GALILEO transmission protocol. *www.u-blox.com*

C-Nav3050 GNSS receiver

The C-Nav3050 GNSS receiver latest range of advances include the addition of dynamic RTCM outputs and choice of either NTRIP client or server mode operability. It also include extended Bluetooth facilities and Ethernet virtual comports, additional Moving Base RTCM Code, Moving Base RTK capability and RTK heading applications; additional internal data logging capacity; improved L1/G1/L-Band modes and autoselect for maximum Net-1/Net-2 C-Nav coverage. *www.cnavgnss.com*

Bentley launches STUDENTserver

Bentley Systems has launched STUDENTserver. This intuitive website offering is available at no charge to schools participating in the Be Careers Network Academic SELECT Subscription program. It provides all students and faculty at these schools with easy, self-serve access to the same commercial-grade software used by leading architects, engineers, and owner-operators to design, build, and operate the world's infrastructure. *www.bentley.com*

SuperGeo partners with GeoViet

GeoViet Consulting, Vietnam is the new distributer of SuperGeo Technologies. It will distribute SuperGIS series software in Vietnam. It integrates geospatial technologies and further improves environmental development and inter-disciplinary communication. *www.supergeotek.com*

Broadcom's GLONASS support

Broadcom announces two new system-on-a-chip (SoC) solutions with support for GLONASS in addition to GPS, marking the first cost-effective, commercially-available, single die SoC solutions that support both systems simultaneously. *www.broadcom.com*

Esri opens R&D center in China

Esri has established a research and development (R&D) center in Beijing, China. The center will provide GIS software development to support China's many growing industries.By employing local software developers, It will help advance the spatial technology expertise of the Chinese workforce and enable China's GIS community to extend its influence to ESRI's global customer base. *www.esri.com*

RIEGL VMX-250 with optional camera

Latest R&D efforts resulted in the optional combination of a calibrated camera system (VMX-250-CS6) with the RIEGL Mobile Laser Scanning System. Providing 3D point clouds and high-resolution images in a seamless workflow in acquisition and processing, the system now shortens schedules, reduces costs and opens new areas of application. *www.riegl.com*

New Trimble Railway solution

The Trimble® GEDO CE Trolley System provide as-built survey and documentation for railway track maintenance and modernization. The new System and software were acquired from Sinning Vermessungsbedarf GmbH of Wiesentheid, Bavaria, Germany. *www.trimble.com.*

India terminates S-band contract

As allegations of wrongful allocation of S-band frequencies for radio waves to a private company is mounting pressure on the Government of India, the government decided to terminate the controversial contract with Bangalore-based Devas Multimedia. It also claimed that it had not incurred any financial losses because of the contract. But the Department of Space conceded it had not fully informed the Cabinet that G-SAT6 and G-SAT6A satellites it intended to launch were meant primarily for use by Devas Multimedia. *www.indianexpress.com*

Iran sets up centre for satellite images

Iran opened its first centre to receive satellite images, a new stage in its space programme that coincides with celebrations marking the anniversary of the 1979 Islamic revolution. According to Defence Minister, Ahmad Vahidi, equipments used in the centre have been manufactured by Iranian engineers. Iran does not have an operational satellite of its own but announced in December, 2011, that it would launch two satellites -- Fajr (Dawn) and Rasad-1 (Observation-1) by the end of the Iranian year in March 2011. *www.spacemart.com*

Images to estimate crop harvest

In order to ensure a good and consistent supply of food it is very important that countries and regions know how much harvest a particular area will produce. Mobushir Riaz Khan at the University of Twente's ITC Faculty in The Netherlands has developed a method for using satellite images to determine which crops are cultivated in which areas. From the perspective of food safety, for the allocation of agricultural subsidies and to make the best possible use of available agricultural land it is vital that policymakers can estimate which crops grow in a certain area and how much harvest they will yield. For a large area it is usually difficult, time-consuming and therefore expensive to determine such matters. With this in mind, Mobushir developed a method for using satellite images to provide accurate estimates of which crops grow where, in what quantities and how much can be harvested. *Source: ITC, The Netherlands*

MARK YOUR CALENDAR

April 2011

6th National GIS Symposium in Saudi Arabia
24-26 April
Khobar, Saudi Arabia
www.saudigis.org

Geo-Siberia 2011
27-29 April
Novosibirsk, Russia
www.geosiberia.sibfair.ru/eng/

May 2011

ASPRS 2011
1-5 May
Milwaukee, Wisconsin, USA
www.asprs.org/milwaukee2011/

Gi4DM 2011
3-8 May
Istanbul, Turkey
www.gi4dm.org

Global Space & Satellite Forum
9-11 May
ANEC, Abu Dhabi
www.gssforum.com

Geospatial Intelligence Middle East
15-18 May
Abu Dhabi
www.geospatialdefence.com

FIG Working Week 2011
18-22 May
Marrakech, Morocco
www.fig.net

Be Together: The Bentley User Conference
23-26 May
Philadelphia, USA
www.bentley.com/betogether

June 2011

2nd Annual Geospatial Summit
1-3 June
Budapest Hungary
www.flemingeurope.com

Trans Nav 2011
15-17 June
Gydnia, Poland
www.transnav.am.gdynia.pl

South East Asian Survey Congress
22-24 June
Kuala Lumpur, Malaysia
www.seasc2011.org

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

July 2011

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

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

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

August 2011

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

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

September 2011

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

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

October 2011

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

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

November 2011

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

ENC 2011
29 Nov-1 Dec
London, UK
www.enc2011.org

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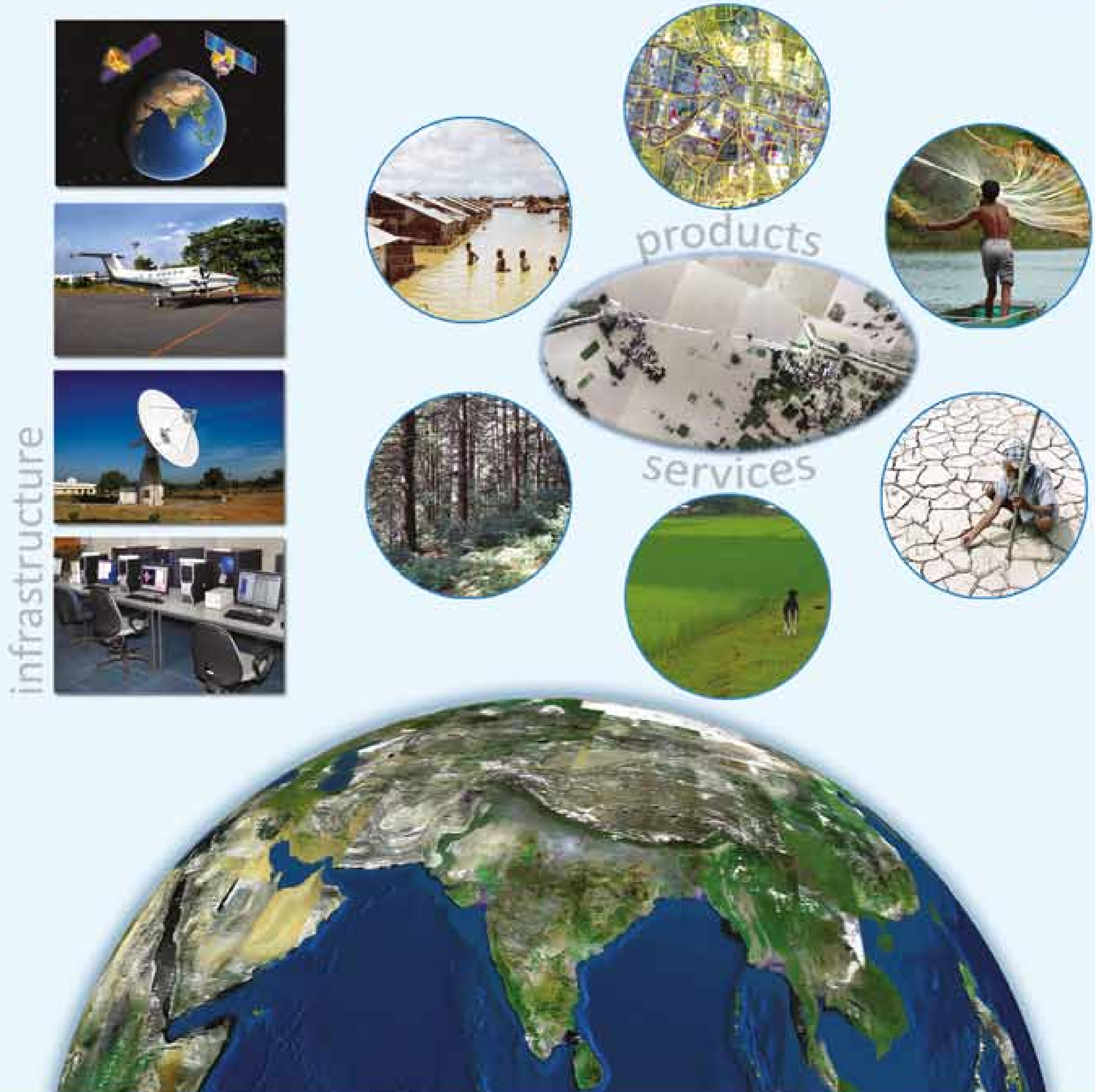

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