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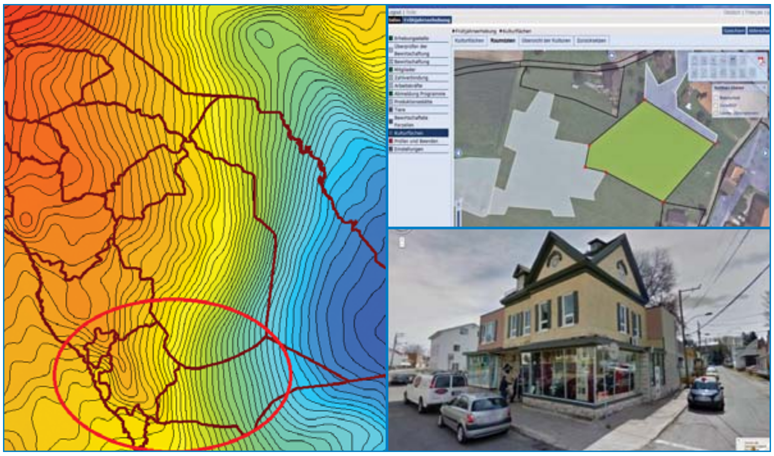

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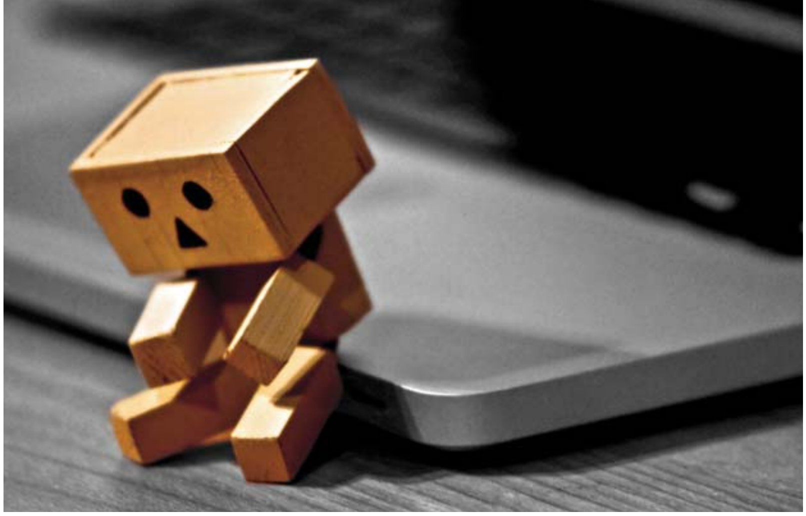

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Bal Krishna, Editor
bal@mycoordinates.org

Legal aspects of navigation

The cases for privacy and liability: An introduction for non-lawyers

Frans G. von der Dunk
Harvey & Susan Perlman Alumni / Othmer Professor of Space Law at the University of Nebraska-Lincoln, College of Law, LLM Program in Space, Cyber & Telecommunications Law, USA

Arguably the issues of privacy and protection of data against undue interference, respectively liability for erroneous positioning, navigation or environmental information and any damage or loss suffered as a consequence of trusting such information, arise as the two most prominent and complex ones

Navigation making use of advanced technologies, notably involving radio-waves providing precise information on positioning, navigation options and on the surrounding geographic environment, has become an ever more present phenomenon in today's societies. Needless to say, this raises also a number of profound legal issues, some more general in nature, some more specific to the navigation sector or even a specific subsector thereof, alternatively taking on a specific flavour once arising in that context.

Amongst those, arguably the issues of privacy and protection of data against undue interference, respectively liability for erroneous positioning, navigation or environmental information and any damage or loss suffered as a consequence of trusting such information, arise as the two most prominent and complex ones. The present paper therefore represents an effort to survey, analyse and evaluate these two issues, with a focus on international and, as relevant, European law as an example of how regional or even national law may further – and often indeed do – interpret the international rules and/or the general principles behind them. Beyond such interpretation and implementation, after all, most national legal systems have their own particular regime in place on both sets of issues.

Navigation from a legal perspective

'Navigation' in reality is of course a multifaceted phenomenon, difficult to capture in a simple scheme. Nevertheless, for the purposes of legal analysis it would be very helpful at the outset to outline its main distinctive elements, dissecting the concept as it were into a few major key categories of components. By way of a default approach for the purpose of allocating the appropriate legal obligations, responsibilities and liabilities navigation systems at this junction should then probably be seen to consist of three such major components. How the problem of privacy protection would then fit into this scheme, is yet another matter.

The first main component comprises the radio-location network, that is the physical infrastructure and the hardware comprising it which provide the baseline services by way of radio-communications – satellites emitting signals-in-space, radio towers emitting radio signals, or even fixed navigation devices at airports using various carriers of electronic messages. Sometimes the operation of the physical infrastructure is separated from that of providing such baseline services over it, and sometimes the baseline services are augmented by the same provider with, for instance, software or information updates, but both together represent the 'supply side' of the navigation sector.

Operators involved on this 'supply side', whether government agencies active to provide services of public interest or commercial operators in it for the money, are usually covering regions, countries or even continents with their operations, in efforts to spread the public services as broadly as possible respectively generate as much revenues as possible. Their key tools for achieving such aims comprise on the one hand the physical infrastructure – which, except for satellites[1], requires appropriate regulation at a national level[2] – and on the other hand the use of radio waves, preferably without undue interference – which means communications law, both at the national but, as for international usage of radio frequencies, very profoundly also at the international level, is applicable and applied[3].

The second main component concerns the on-board devices, whether highly advanced ones such as on board aircraft or ships or far more simpler ones, all the way up to those carried by mountaineers, hikers, amateur sailors and suchlike. Sometimes these devices come with the vehicle, sometimes they can be bought as stand-alone units to be summarily installed in such vehicles – or are just carried in hand or backpack; but in all cases it is the hardware on the 'demand side' of the navigation equation we are concerned with here.

Consequently, one main important legal regime applicable concerns that of product liability law; the applicable set of laws and regulations to ensuring that no 'unsafe' products are marketed and sold to unsuspecting consumers. Such product liability law is by and large of a national nature, although within the European Union substantial efforts have been made to harmonize the national product liability laws of the EU member states[4]. In addition, various – always national – legal regimes may apply regarding compliance with *a priori* technical standards which certain products would have to comply with, or general product warranties and guarantees.[5]

The third component, also operative on the 'demand side' yet usually taken care of by a different branch of the sector, concerns the (provision of the) software calculating positions and providing further navigation information, even if sometimes it may well form physically part of the on-board device, alternatively be provided by the infrastructure network (service) provider.

To the extent this third component is subject to legal and regulatory constraints and controls, they again would largely form part of national systems – this time focusing on *service* warranties and guarantees – as well as being in all remaining aspects usually dealt with by contractual agreements, where 'the law' usually only provides certain broad parameters within which waivers and disclaimers are considered allowable.

Two major areas illustrating the relevance of such an analysis and of the effort to dissect the complex navigation environment into a few key categories of services and providers, are indeed those of privacy and liability. Take, for instance, the fundamental risks that information on a user's whereabouts are unduly distributed or that the user is provided with information which is erroneous or even absent at a critical juncture.

For legal purposes of determining responsibility for any violation of privacy in such a scenario it is of fundamental importance to understand that (contrary to public perceptions) GNSS satellites, in and of themselves, have no knowledge whatsoever of a particular user's position – and can therefore never be held responsible for such a violation. If the above generic threefold subdivision of the navigation sector is to be summarily applied, most likely the privacy violation would come to be attributed to the operator of the third component.

Likewise, if liability for damage caused by a user's trust on navigation information which subsequently turns out to have been unjustified is to be allocated, it should be realized that GNSS satellites, so far, do not provide the key positioning and navigation information – that is done by the on-board device using triangulation algorithms, or off-board infrastructure using the triangulated information communicated by the on-board device and feeding back the actual positioning and navigation information.

To analyse and try to appreciate in somewhat greater substance how such scenarios are to be approached from a legal perspective, it is thus appropriate to now address these two concepts of 'privacy' and 'liability' a bit more in detail.

Privacy: the definition and the law

Due to the many legal documents (laws, treaties and others) having addressed the issue of 'privacy' in one way or another, many definitions of the concept exist, some extended, other much more concise. For the present purpose however it should suffice to define the 'right to privacy' as a 'right of individuals or groups of individuals to seclude themselves and limit information about themselves becoming publicly available'.[6]

In real life, this right to privacy falls apart in two main categories. The first category refers to the problem of 'Big Brother': governments should abstain from any undue interference with an individual's privacy, unless there are clearly overriding interests of a public nature, as based on non-discriminatory, transparent and coherent criteria. The second category refers to the problem of 'paparazzi', under which governments should also protect individuals against unjustified intrusion into their private life by *other* private persons and/or, following from there, the public at large. Finally, it should be noted that increasingly the right of privacy is also considered to apply to companies and other legal entities, not just to natural legal persons, read human individuals.[7]

Legally speaking, the right to privacy has been treated as part of the human rights catalogue. Thus, the famous 1948 Universal Declaration on Human Rights of the United Nations provided: "No one shall be subjected to arbitrary interference with his privacy, family, home or correspondence, nor to attacks upon his honour and reputation. Everyone has the right to the protection of the law against such interference or attacks."[8] A further UN-initiated international treaty of 1966 similarly stated: "1. No one shall be subjected to arbitrary or unlawful interference with his privacy, family, home or correspondence, nor to unlawful attacks on his honour and reputation. 2. Everyone has the right to the protection of the law against such interference or attacks."[9]

These international treaty rules have been widely implemented in national law. For example, in the United Kingdom the 1998 Human Rights Act stated:

1. Everyone has the right to respect for his private and family life, his home and his correspondence.
2. There shall be no interference by a public authority with the exercise of this right except such as is in accordance with the law and is

> necessary in a democratic society in the interests of national security, public safety or the economic well-being of the country, for the prevention of disorder or crime, for the protection of health or morals, or for the protection of the rights and freedoms of others.[10]

As a matter of fact, this clause *exactly* repeats the text of Article 8 of the 1950 European Convention on Human Rights, which thus resulted in a European-wide harmonization of at least the definition of '(the right to) privacy', even as individual sovereign states remained at liberty to apply for instance criminal law sanctions and procedures in accordance with their respective domestic traditions and laws.

Interestingly, much later in the context of EU law it became necessary for the issue of privacy to be dealt with from quite a different angle, in the context of steadily increasing digitalization and 'electronization' of data, including personal data, and the use of internet, e-mail and suchlike for exchange of and access to data. The approach in the European Union was to achieve a fair and appropriate balance between the human right of privacy, the protection of which now required some safeguards in the specific context of the enormous traffic in electronic data, and the economic interests in generally allowing, even stimulating such traffic of and general access to data as a major driver of new commercial services and activities.

This approach resulted in a key EU Directive in 1995, the 'Data Protection Directive', which was amended and updated in 2002 to take into account new developments in the ICT realm, which now spells out the details of privacy protection in the area of electronic data – which, as for the navigation sector, includes electronic data referring to an individual's precise position or route followed.

Based on a key definition of 'personal data' as "any information relating to an identified or identifiable natural person",[11] there are three generic categories of exceptions to the fundamental requirement that whatever takes place on electronic networks in terms of data transfers and access should not amount to infringement of an individual's right to a personal life and privacy. By and large, the same or similar exceptions will be found in national law regimes in other states outside of the European Union fundamentally upholding the rule of law and protecting human rights – albeit often in different versions and variations.

Privacy-sensitive data can be legitimately accessed and used without consent of the data subject only if justified by overriding public interests which have to be explicitly spelled out in applicable law and regulation

First, the so-called 'data subject' may provide his consent to the use of specific electronic data.[12] An obvious example in the navigation context would be where an individual wishes to enjoy specific services which are related to his specific location or route. A main condition is that the consent should be unambiguous and explicitly, knowingly and willingly provided. Furthermore, the extent of the consent also principally determines the extent to which an operator enjoying legitimate access to such privacy-related data can actually use those data – in other words, the latter may not after acquiring access to data for one purpose or service then use such data also for other purposes or services.

Second, privacy-sensitive data can be legitimately accessed and used without consent of the data subject *only* if justified by overriding public interests which have to be explicitly spelled out in applicable law and regulation, limited usually moreover to the interests in public order, criminal law enforcement and security.[13] Naturally, those justifications only legitimize access and use by appropriate governmental authorities also as determined by law or regulation, not by other governmental authorities or any private person or entity – and again those data may *only* be used for the specific purposes specified by the applicable law or regulation.

Third, data which may have privacy-sensitive content may commonly be collected and used for general historical, scientific and statistical aims and analyses – if properly made anonymous, meaning that individual data cannot be traced back to an individually identifiable person or specific group of persons.[14]

Obviously then, throughout the EU member states anyone providing positioning and navigation services should ensure proper protection of data regarding the position and navigation of individual users, both in a technical sense – by developing secure networks and data streams – and in a legal sense – by ensuring that data subjects are properly informed and if necessary have given their consent, whereas governmental authorities should only be allowed access in conformity with specific law and regulation. Generally, moreover, these exceptions to potential infringement of personal privacy should be interpreted in a narrow sense: protection of personal data is the default, access by others than the data subject the exception. Again, other non-EU domestic legal systems respecting the rule of law and the protection of human rights would by and large follow the same approach.

Liability: the definition and the law

Liability likewise is a very common and often-used concept, hence defined throughout the ages in myriad fashion. For the purpose of the present analysis, however, the following definition should suffice: liability is "the legal accountability of a person or legal entity to compensate for damage caused to another person or legal entity in accordance with specific legal principles and rules", which principles and rules are furthermore to be based upon specified sources of law.[15]

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In other words, liability is not a self-evident consequence of damage being caused to someone, but depends on a particular source of law – treaty, act, customary law – which is applicable to the case of damage at hand, and amongst others determines who is liable to whom, for what (kinds of damage), and to what extent. It determines whether fault liability (that is, the victim needs to prove some kind of fault has caused the damage before compensation can be claimed) or absolute liability (that is, the causal link between the damage and the defendant is sufficient for compensation to be due) applies, and it also determines the level of compensation – unlimited or subject to limitations?

As a consequence, also, there are many different legal regimes dealing with liability, national as well as international,[16] and in some cases even at the level of the European Union. At the highest level, three different regimes should be distinguished.

First, there is the concept of third-party liability, often at the domestic level also labelled or comprised within tort liability, which is liability for damage caused to parties not as such involved in the activity in the context of which the damage occurs. Such liability by definition is regulated by law, whether by statute or by customary or common law, where each national legal system includes such a regime and in addition in a number of areas also international rules exist. In the absence of any legal regime of third-party or tort liability specifically targeted at navigation- or positioning-related damage,[17] reference could still be had to established general principles of law to claim liability.[18]

Second, contractual liability, often also referred to as inter-party liability, rules damage caused by one contracting party to another in the context of the activities contracted for. By definition, this is regulated as between those contracting parties by way of the applicable contract. General law only rarely steps in (for example to ensure contractual agreements do not violate other laws or fundamental principles of morality or justice); normally the freedom of contract of the parties rules supreme here.

Throughout the EU member states anyone providing positioning and navigation services should ensure proper protection of data regarding the position and navigation of individual users, both in a technical sense – by developing secure networks and data streams – and in a legal sense – by ensuring that data subjects are properly informed and if necessary have given their consent

Third, the earlier-mentioned concept of product liability represents an exception to the above two types of liability, which basically apply to damage caused by an *activity*, whereas product liability of course focuses on damage caused by a particular *product* in the course of normal or reasonable usage.[19]

For the realm of navigation, the above liability-labyrinth essentially means that for each case of damage caused in the context of a navigation service or product, the applicable legal regime(s) has/have to be identified, which then spell(s) out in detail what damage is compensable to what extent by whom under which further conditions.[20]

The GNSS Legal/ Functional Model

To illustrate the resulting complexity of the liability situation in particular where the involvement of satellites in navigation arises, in the context of several major advisory projects on Galileo the present author has developed a 'GNSS Legal/Functional Model' to properly map the various potentially or actually applicable liability regimes in this realm. This model could be applied to GPS, GLONASS, EGNOS or any other relevant satellite navigation context as much as to Galileo; equally, it could be applied with greater precision and in greater detail to specific areas where GNSS is used – aviation, maritime, road, rail, location-based services, time stamping, geodesy, *et cetera*.

Note of course, that – like any model – this is a mere approximation of reality; the types of liability specified in the legend below should not be seen as exclusive, but rather as the 'normal', most commonly applicable state of affairs. Any full-fledged analysis offering comprehensive coverage requires the appropriate legal expertise.

This 'GNSS Legal/Functional Model' thus allows a first level of mapping of specific liabilities as per specific legal regimes based on the applicable legal sources, in principle for any relationship between the various (groups of) stakeholders in the navigation environment.

A few illustrations here to make the general point.

First, **E** in the case of satellite service – notably GNSS signal and service – providers refers to the aforementioned 1972 Liability Convention – but then only to the extent the damage concerned comprises physical damage to third-party victims on the ground *caused directly by the satellites* – not to any damage resulting from flawed navigation information. Whether any regime of sufficient specificity applies to the latter categories of damage, would indeed be highly disputable; at best general tort liability principles may be applied. Certainly, GPS and GLONASS do not accept such liabilities, so that the chances of actually getting liability acknowledged by a domestic court or tribunal *and* effectively being effectuated are rather slim.

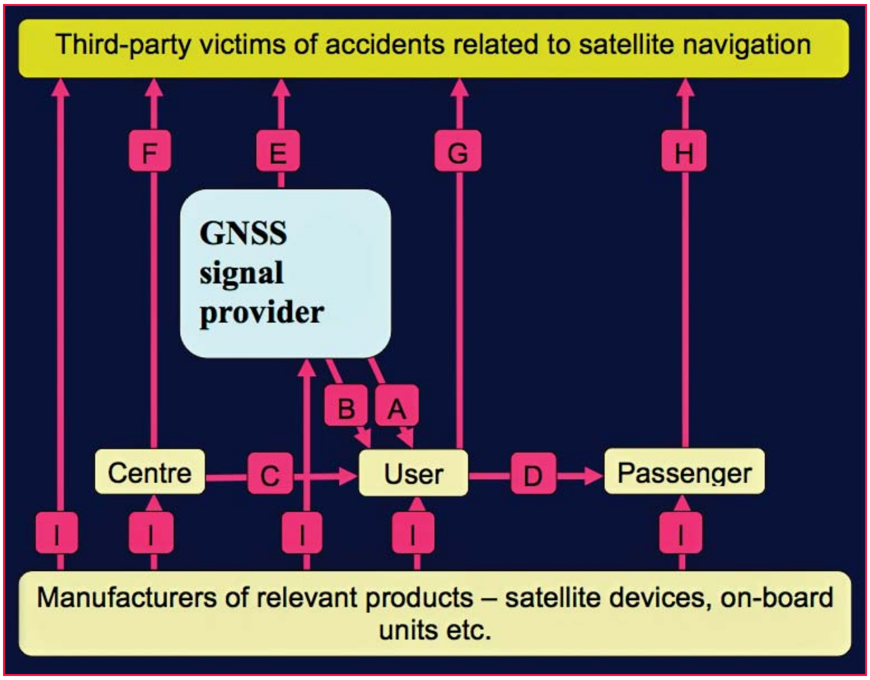

Figure 1: The Galileo Legal/Functional Model and liability in a multi-model context
Legend: A = No (or tort?) liability; B = Contractual liability (possibly including onward liability handling); C = contractual liability (normally, except for aviation); D = contractual liability (unless overruled by tort liability / national or international law imposing liability regime); E = International third-party liability; F = No (? or tort?) liability; G = Third-party liability (usually national, sometimes international); H = No liability (normally); I = Product liability as applicable (national or EU law)

Second, where GPS and GLONASS operators insist on **A** being applicable *vis-à-vis* users, no contract of whatever nature existing regarding such use of GPS or GLONASS signals. This, *inter alia*, means that in aviation GPS and GLONASS are not acceptable for safety-sensitive signal provision, in the absence of any contractual warranties or liabilities. International regulation as per ICAO simply obliges aviation to use navigation aids only if compliant with high standards of reliability and precision. Any Centre in the aviation context – read air traffic control centres – would thus only allow aircraft operators to use a GNSS signal under some form of contract giving rise to **B**.

This is precisely one area where Galileo intends to make a difference, aiming for contracts giving rise to **B** in appropriate circumstances. Against payment, the Galileo operator will thus possibly offer contractual liability properly speaking – for instance for damage caused by electronic signals overheating the receivers. However, this is not what GNSS users are usually most concerned with, so the Galileo operator would also be expected to add service guarantees and warranties as part of **B**, specifying compensation in case the service fails to meet the promised standards, as well as guarantees that if flawed Galileo-based positioning- and navigation-information would result in onward damage, Galileo would accept liability for damage under for example **D** or **G**, which is indirect damage as far as the relationship between the signal provider and the user is concerned.

Third, when again taking aviation as the example, **D** covers a broad range of international treaties on contractual liability of airlines *vis-à-vis* their passengers for damage sustained during a flight – ranging from a 1929 Warsaw Convention to a 1999 Montreal Convention – which have by and large harmonized the national laws of the various groups of states parties to the respective treaties. In handling damage caused by aircraft accidents to third parties on the ground, **G** by contrast comprises, at the international level, only a sparsely ratified 1952 Rome Convention, later amended by a similarly sparsely ratified 1978 Montreal Protocol, which means that in most cases national (tort) law applies here, with all variations possible as between individual countries.

Obviously, for other modes of transportation (interested in) using GNSS signals and services, a largely or even completely different set of legal regimes would elaborate the various letters in this GNSS Legal/Functional Model, except for the rather generic and separate product liability represented by **I**.

Again, however, for a comprehensive and full-fledged legal analysis more detailed knowledge and understanding *both* of how satellite navigation works *and* of any potentially applicable legal regimes in a given scenario are necessary than can be reflected in the current overview.

Concluding remarks

As can also be glanced from the GNSS Legal/Functional Model – which could, with minor changes, be applied also to areas such as privacy rights, next to those of liability which the version briefly discussed above focussed on – law often is simply a matter of common sense: one has to look for the applicable relationship, and then find the legal sources applicable to that relationship, to seek out whether liability for damage might be claimed, and if so, to what extent, by whom to whom and under what further conditions.

The baseline approach for meeting privacy concerns in the context of navigation operations further to that is that privacy in the first place is a matter of consent, unless specific criminal and/or security-related law allows for infringement of such privacy. In all cases, however, such infringements need to be interpreted narrowly, and infringement of privacy is then *only* allowed proportionally, that is to the extent of the consent respectively the applicable provisions in the law.

Similarly, the baseline approach for addressing potential liabilities is a matter of following the chain of relationships between various stakeholders, and determining the appropriate regime(s) for the appropriate link in the chain. Where issues become too complicated from that perspective, however, one would be well-advised to involve a lawyer and/or some insurance.

Where, finally, in many respects the law has not yet dealt at any level of detail with navigation-related or -specific privacy issues or liabilities, not only much work remains still to be done in the legal realm, but it would be highly advisable for any stakeholder in the sector to follow and, as far as feasible and justifiable, influence that process in order to arrive in the end at a (much more) logical, comprehensive, transparent and balanced legal regime allowing navigation to offer its benefits to mankind and individual societies without unduly interfering with the right to privacy and whilst taking appropriate care of liabilities for damage.

> The baseline approach for addressing potential liabilities is a matter of following the chain of relationships between various stakeholders, and determining the appropriate regime(s) for the appropriate link in the chain

Endnotes

[1] With regard to satellites, since the 1960s a major body of international law has developed, allowing in principle (and then regulating) the use of outer space for peaceful purposes, most notably by way of the 1967 Outer Space Treaty. Over a dozen states globally speaking have in addition drafted national space laws applicable to such operations, usually in conformity with this body of international obligations – but the overwhelming majority has not (yet) undertaken such domestic implementation efforts.

[2] Thus, each state has for instance regulations on the instalment of radio towers for cellular telephony on public or private grounds. These regimes have not been subjected to international treaty obligations, partly since the impacts of building a cell tower are so much of a local nature.

[3] This regime at the international level has been developed largely under the auspices of the International Telecommunication Union (ITU), most particularly the Radio Regulations updated every few years under its *aegis* and the process for allotting and assigning radio-frequencies to specific international communication infrastructures. At the national level, each state has not only established a domestic legal structure to ensure relevant international obligations are complied with, but also extensive regulation in place concerning radio-communication activities that remain of a purely domestic nature.

[4] This was first done by way of a 1985 Directive, which has been fundamentally updated in 1999.

[5] At the international level, the International Organization for Standardization (ISO) merely acts by way of issuing relevant recommendations on standards for ranges of products (and services) which may impact a particular country's legal handling of product liability (standards), but leaves the discretion to do so with individual countries.

[6] See *e.g.* for relevant general and fairly succinct yet comprehensive definitions http://en.wikipedia.org/wiki/Privacy; http://legal-dictionary.thefreedictionary.com/privacy; and http://www.encyclopedia.com/topic/right_of_privacy.aspx.

[7] *E.g.*, in Europe in the 2002 *Colas Est* case companies were considered entitled to enjoyment of the right to privacy as well.

[8] Art. 12, Universal Declaration of Human Rights.

[9] Art. 17, International Covenant on Civil and Political Rights.

[10] Art. 8, Human Rights Act.

[11] Art. 2(a), Data Protection Directive.

[12] *Cf. e.g.* Art. 7(a), Data Protection Directive.

[13] See *e.g.* Arts. 3(2), 8(4), (5), 13(1), Data Protection Directive.

[14] See *e.g.* Art. 6(1)(b), Data Protection Directive.

[15] *E.g.* Art. 2, Co-operation Agreement On a Civil Global Navigation Satellite System (GNSS) between the European Community and its Member States and the State of Israel, Brussels, 13 July 2004.

[16] The international regimes usually insist that domestic legal regimes are harmonized to the extent that the international regime in question requires, whilst it remains in most cases the *national* regime which is directly applicable to instances of damage.

[17] Only in the aviation sector notable efforts have been undertaken in the context of the International Civil Aviation Organisation (ICAO) to create such a regime for the use of GNSS, but these efforts have consistently been rebuffed by the actual providers so far of operational GNSS services, the US and Russian military establishments running GPS respectively GLONASS.

[18] *E.g.*, in public international law the legal principle '*sic utere tuo ut alienum non laedas*' holds states liable for harm caused from their national territory (in other words, from within their legal control) to other states.

[19] *Cf.* also however the aforementioned EU Directives of 1985 and 1999, which harmonized such domestic regimes as for the EU member states.

[20] Thus, by way of example the 1972 Liability Convention spells out that physical damage directly caused by a 'space object', read *inter alia* a GNSS satellite, to a state or its citizens has to be compensated by the launching state(s) of that space object, without any principled limit as to the amount to be compensated and subject to a requirement of proof of fault only if the damage is sustained by another space object; otherwise, absolute liability applies.


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Towards spatially enabled Societies and Governments

The future of spatial enablement and the realisation of a spatially enabled society, lie in it being a holistic endeavour where spatial (and land data) and non-spatial data are integrated according to evolving standards and with the SDI providing the enabling platform

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The rapid development and increased demand for spatial information infrastructures in many jurisdictions have made spatial information an invaluable tool in policy formulation and evidence-based decision making.

Spatial enablement, that is, the ability to add location to almost all existing information, unlocks the wealth of existing knowledge about social, economic and environmental matters, playing a vital role in understanding and addressing the many challenges we face in an increasingly complex and interconnected world. Spatial enablement requires information to be collected, updated, analysed, represented, and communicated, together with information on land ownership and custodianship, in a consistent manner to underpin good governance of land and its natural resources, whole-of-government efficiency, public safety and security towards the well-being of societies, the environment and economy.

The main issue societies have to focus on is probably less about spatial data, and more about "managing all information spatially". This is a new paradigm that still has to be explored, deliberated and understood in the context of a spatially enabled society.

Challenges that societies are facing

When looking at international media reports, there are many examples where there is a strong need for sound land information and good land administration and management systems. Phenomena such as urban sprawl, overpopulation, pollution, traffic congestions, inefficient transport systems, disaster management, land grabbing, and environmental sustainability need our full attention. In order to manage and handle those issues, basic information including land ownership is required about the land and location where they take place.

Spatial information and technology is proving to be an effective tool in addressing such complex and multi-scale challenges. The notion of spatial enablement, and a spatially enabled society, is a reference to the use of spatial technology across all levels of society – government, industry and citizens, to improve decision-making, transparency and increase efficiency. It is essential that land and spatial information practitioners provide the link to ensure that both the social and technical systems in which spatial enablement will operate are well understood: spatial enablement can only be effective when designed according to the specific needs of the jurisdiction.

Role of Land Administration and Land Management

A spatially enabled society needs well organized and efficient land administration and land management systems. They are serving the particular needs as mentioned above and support the infrastructure to achieve the triple bottom line of sustainable development.

More recently, the term 'land governance' has been introduced, conceptualized as an elaboration of the broad notion of 'good governance' with particular relevance to land management issues. It has become a widely accepted concept and generally refers to 'the policies, processes and institutions by which land, property and natural resources are managed'. This includes access to land, land rights, land use and land development: essentially, land governance is about determining and implementing sustainable land policies and inherently the legal and institutional framework for the land sector.

Therefore, land administration systems provide the basis for conceptualising rights, restrictions and responsibilities; land administration functions form the operational component of land management; land governance enables the determination of land policies that direct land administration systems and land management practices so that these can be effectively implemented to ensure sustainability.

By bringing together the various strands – land administration, land management and land governance – we can create a strong framework by which land and natural resources can be effectively managed to fulfil political, economic and social objectives, that is, to help realize sustainable development objectives.

Key elements for a spatially enabled society

In order to support this concept, the Task Force identified six elements, which are critical to its implementation. Without those six elements, the spatial enablement of a society or government would seriously be held back in its progress. They are:

Legal framework: to provide a stable basis for the acquisition, management, and distribution of spatial data and information;

Common data integration concept: to facilitate that existing spatial data – from government as well as other sources – respect a common standard in order to ensure interoperability and linkage of data for the benefit of all;

Positioning infrastructure: to provide a common geodetic reference framework in order to enable the integration of spatial data and information;

Spatial data infrastructure: to provide the physical and technical infrastructure for spatial data and information to be shared and distributed;

Landownership information: to provide the updated and correct documentation on the ownership and tenure of the land, fisheries, and forests, without which spatial planning, monitoring, and sound land development and management cannot take place;

Data and information concepts: to respect and accommodate the different developments in the acquisition and use of spatial data and information.

Tasks	Land related activities	Tools / Methods
Strategy • visions and objectives	Land policy	• political activities
Management • measures and projects for the implementation of the policy	Land management 	• land-use planning • land consolidation • land reallocation • melioration • landscape development • land recycling
Administration / Documentation • handling of spatial information, data analysis, data visualization • cadastral operations, data modelling, data acquisition, data maintenance, data distribution	Land administration and cadastre 	• monitoring • navigation • geoinformation • land registration • cartography • surveying • geodesy

Figure 1: Broader context of land documentation, land administration, and land management

In terms of keeping a society spatially enabled, there are probably further issues that need to be considered, namely the educational framework, the technical and institutional development of spatial data management, the development of awareness on all levels of society – such as citizens, institutions, and decision-makers – and the development and applicability of land management tools in order to make best use of spatial data. These elements, however, were not further discussed in the Task Force.

Legal framework

The legal framework is a key element in achieving SES as it constitutes an integral component of a jurisdiction's institutional structures. The framework depends on the set of laws and regulations that govern behaviour and create institutional arrangements within a jurisdiction to facilitate the use, sharing, access and management of spatial information, services and technologies within, and between, different levels of society. Consequently, these also underpin the mechanisms of a jurisdiction's spatial data infrastructure (SDI) as an enabling platform.

The ability of spatial data sharing and interoperability by reconciling often competing legislative policies poses a significant challenge. This is of particular significance for spatially enabled datasets as they often have multiple uses that were not anticipated in the original licensing conditions or in its creation, which could increase the risk of litigation should injury result from the inappropriate use of the data. One of the ways in which an SDI, as an enabling platform, can support the legal framework is to provide an avenue for governance. Governance plays a central role in SDI, and therefore SES, by enabling the creation of agreements that bind together the people and geospatial resources (data and technology) involved.

Common data integration concept

At first sight, a common data integration concept seems to be a rather technical issue. However, it has a highly political and institutional relevance, as depending on the concept, valuable information is either locked into data silos or it can satisfy the aspects of true interoperability and data sets can be shared and linked between the different stakeholder. Only then, a society can benefit as a whole.

There are three key elements for successful data integration: respect of the independence of the legal and institutional responsibilities / use of the same geographic reference framework / use of the same standardized data modelling and description concept. When these three key elements are respected, the linkage of data sets is facilitated and the wealth of geoinformation can be taped into.

Positioning infrastructure

The geodetic datum is widely recognized as the most fundamental layer of any spatial data infrastructure. Traditionally, it has been realized through the placement of permanent survey marks and carrying out surveys to generate accurate latitudes, longitudes and heights for those marks. A global trend during the last decade has been to move away from survey marks and to establish Global Navigation Satellite Systems (GNSS) supported by Continuously Operating Reference Stations (CORS). These enable a high accuracy and a continuously monitored realization of the geodetic datum.

GNSS can be considered as a most truly global infrastructure available today. They underpin the broad spatial enablement of our societies by providing the ubiquitous ability to hundreds of million mobile phone users to locate themselves and to obtain location based services. The ubiquity also creates hunger for improved performance, which helps to make GNSS evolve from an industrial to a mass market application, supporting navigation, road safety, vehicle guidance, collision warning, etc.

The implementation of higher quality infrastructures, such as CORS, providing even higher accuracy can only be justified in densely populated areas, while the extension into rural and remote areas makes sense, only when the business case is broadened beyond surveying and spatial data, for example for machine guidance in agriculture, construction or mining. As such, the positioning infrastructure will come to be seen in the coming years as the fifth infrastructure after water, transport, energy, and telecommunications.

Spatial data infrastructure (SDIs)

SDIs have emerged as both a fundamental network infrastructure, as well as an enabling platform to help achieve the vision of a spatially enabled society as it aims to connect people to data to facilitate decision-making. An SDI comprises both social and technical components: people, access network, policy, standards and data. As such, the successful development and implementation of an SDI depends on understanding the significance of human and community issues, as much as technical issues, which impact on the exchange and sharing of spatial data and services; that is, its interoperability with other systems and information.

The concept of SDIs has evolved with time, resulting in three main approaches – hierarchical, network and most recently, that of a marketplace. The role that SDI initiatives are playing has also changed from being organisation-based, to becoming an enabling platform for SDIs of different scales and hierarchies. A growing demand for access to timely and precise spatial information in real time about real world objects to support more effective cross-jurisdictional and inter-agency decision-making in priority areas has resulted in SDIs becoming a key infrastructure in realising a spatially enabled society.

Landownership information

Land ownership is connected with 'place', as it concerns ownership, value and use of a defined lot of land. Depending on the jurisdiction, this lot of land can have various spatial dimensions, from a single point value to an accurate representation of its boundaries. The usual representation, however, is the 'cadastral parcel', which is uniquely defined to also make it suitable to serve as the key data element for the spatial reference.

The cadastral parcel finds itself defined as a core element of the EU INSPIRE Directive, for which the specifications were developed as official guidelines. Also on national levels, the cadastral parcel is a core element of geodata infrastructures providing land ownership data to authentic base registers.

As such, cadastral parcels are part of something bigger, called land administration system. It is generally accepted that a LAS is to be based on land ownership data.

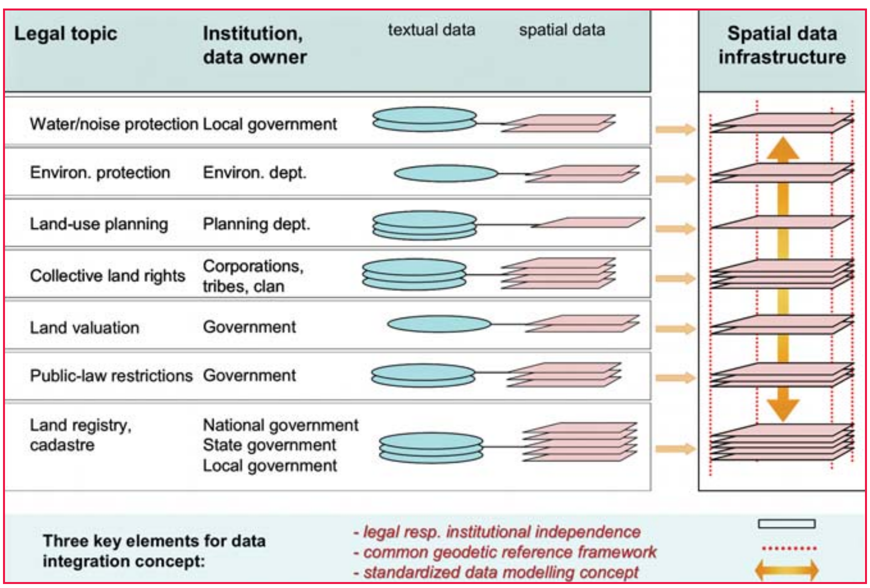

Figure 2: Three key elements for the data integration concept: legal/institutional independence, common geodetic reference system, and standardized data modelling concept

Data and information concepts

Along with the digital revolution, geodata and location data are nowadays managed and consumed in digital form. Electronic mapping, smart phones, Google maps, Bing maps, location based services, meeting friends and finding local restaurants are all mainstream applications in the ‘location revolution’.

The sources of geodata stem from the public as well as the private sector. The public sector establishes basic geodata infrastructures on national as well as international levels, while the private sector provides initiatives such as satellite imagery, open street map, or other crowd-sourced data. The traditional role of Governments collecting official geoinformation is more and more challenged by private sector activities, which however often suffer in terms of systematic and consistent coverage and unknown quality. The future developments will be interesting to follow as global technology companies understood the power of location and their strategies reach far beyond existing markets using location as just one market element. The fusion of different sources of geoinformation will be transforming the geospatial information landscape as society has access to an ever increasing set of geospatial information and associated location based information. The delivery of these innovative services using the billions of mobile phone users across the world will ensure to reach a fully inclusive spatially enabled global society.

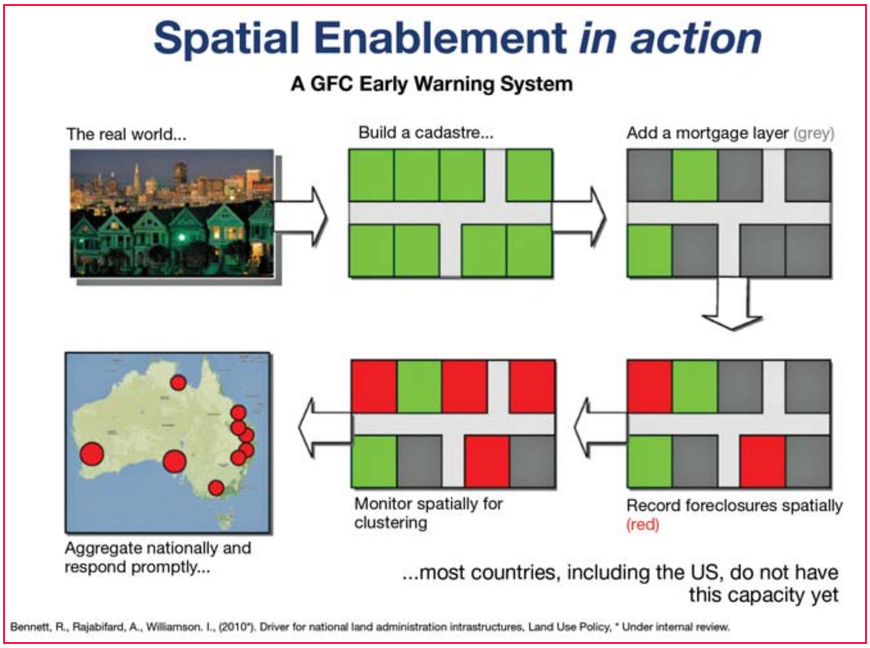

Figure 3: Spatial enablement in action (from Bennett et al., 2012)

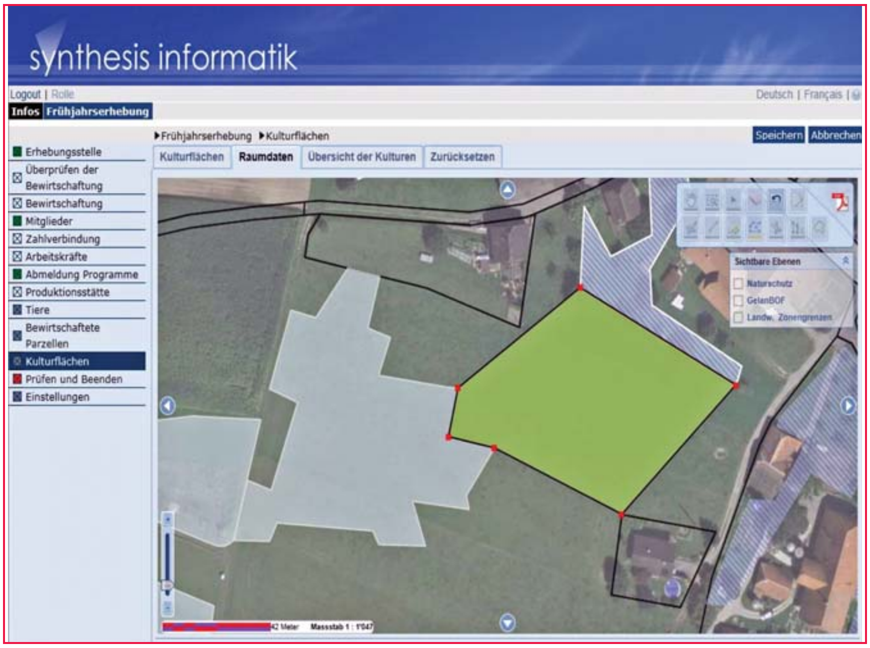

Figure 4: Prototype of web-based tool for farmers indicating their cultivation areas for annual subsidies. © Synthesis Informatik, Gümligen, Switzerland, www.syn.ch.

Discussion and examples

The development of a society towards spatial enablement can be thought of as a continuum over several steps, which may happen for each key element at different speed. When a society has attained full spatial enablement, decision-making procedures may become feasible, which were not possible before. The following two examples illustrate what this might be.

A first example shows how the cadastral landownership layer can be complemented with mortgage and foreclosure information. Such information can then be aggregated at a state or national level, which allows detecting patterns or clustering phenomena. The spatial representation of such phenomena can serve important political decision-making processes (see Figure 3).

Another example is a project in Switzerland, where a web-based portal is being developed for farmers to declare their annual cultivation areas online. Farmers are receiving subsidies on the basis of the crops and areas that they are cultivating. Based on the cadastral landownership and an orthophoto layer, the portal offers tools such as easy-to-use snapping functions and standard forms to be filled out (see Figure 4). This will allow a much more direct and efficient notification process for farmers to provide their data and receive their subsidies. Such a solution would not be possible without a complete documentation of landownership and the interoperability of the information, both of which are in place in Switzerland.

Future directions

The future of spatial enablement and the realisation of a spatially enabled society, lie in it being a holistic endeavour where spatial (and land data) and non-spatial data are integrated according to evolving standards and with the SDI providing the enabling platform.

The concept of SES is offering new opportunities for government and wider society in the use and development of spatial information, but it needs to move beyond the current tendency for the responsibility to achieve SES to lie solely with governments. SES will be more readily achieved by increasing involvement from the private sector, and in the same vein, if the surveying and spatial industries start to look toward other industries for best practices in service delivery.

Future activities need to take into account emerging trends in geospatial information and the new opportunities they present for the application of spatial technologies and geographic information. Future activities will essentially need to be fit-for-purpose, ubiquitous, transparent and seamless to the user. Additionally, there is also a need to consider the developing challenges that are arising from having differing levels of maturity in use and management of geospatial information, and perhaps a need to increase the focus on critical areas that are proving to be challenging.

Even as we begin to think about what the future of SES may look like, at its heart, the realisation of SES will always be predicated on the legal framework, data integration abilities, positioning and network infrastructures, landownership information and the various data and information principles. These key elements need to be embraced by the established professional communities or otherwise they face the threat of being taken over by those groups that better understand the messages of change. As surveyors, land and spatial information specialists, it is imperative that we understand the technological changes, developments and possibilities, so that we can convey these messages and requirements to our partners, to political decision-makers, and to society at large.

In 2009, the FIG established a Task Force to look into the issue of «Spatially Enabled Societies» (SES). A three-year effort together with representatives from GSDI and PCGIAP led to a publication compiled and edited by Dr. Daniel Steudler, Chair of the FIG Task Force on Spatially Enabled Society, and Prof. Dr. Abbas Rajabifard, President of the GSDI Association. The publication is available as FIG-Publication No. 58 from www.fig.net.

The contributions for the six key elements come from Jude Wallace, Serene Ho, Jürg Kaufmann, Matt Higgins, Paul van der Molen, Robin McLaren, Abbas Rajabifard and Daniel Steudler. The summaries for this article have been edited by the authors.

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Terrestrial LiDAR capabilities for cadastral modelling

The paper presents a comparison of terrestrial LiDAR and Distancemeter for surveying 3D spatial data of property units (indoor and outdoor) and producing cadastral representations (2D and 3D).

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3D cadastre models are recognized as valuable solutions to provide enriched spatial representation for overlapping properties, above-ground and subsurface infrastructures, mining rights, etc. (Paulsson and Paasch, 2013;Pouliot et al., 2011; Stoter et al., 2013).

Cadastral plans and 3D models provide help to a variety of users and tasks depending on the country (van Oosterom et al., 2011). Mainly, they are used to support property identification and registration, and to provide spatial foundations for the security of real estate transactions. One prerequisite for producing 3D cadastral models is having access to 3D spatial data (indoor and outdoor) of the property unit (Jazayeri et al., 2014). For cadastral purposes related to apartments with co-ownership units, the third dimension of spatial data may be expressed as vertical elevation (orthometric or ellipsoidal altitude) or Z coordinates of the boundary unit, height of the building level, or volume of the legal 3D units.

Various land survey instruments are currently used to acquire such 3D spatial data, including GNSS/GPS, total station, stereo-photography, Distancemeter (laser rangefinder), and terrestrial LiDAR (laser scanner). A recent questionnaire sent to members of the professional association of land surveyors in the province of Quebec, reveals that the field instruments currently used to survey vertical data for apartments with co-ownership units are Distancemeter, ribbon, total station and GPS. Photogrammetry and terrestrial LiDAR are less popular instruments. When the same land surveyors were asked what they anticipated practices in 10 years to be, LiDAR is foreseen as the instrument having the highest progression (from 8% to 47%) to survey vertical cadastral information of apartments with co-ownership units.

Based on this input, the issue of identifying the capabilities of terrestrial LiDAR instruments to survey 3D lots for apartments with co-ownership units appears important and relevant. Terrestrial LiDAR is used for a wide variety of applications such as city modelling, robotics, archaeology, agriculture, or in the mining industry, (Shan and Toth 2008). However, as far as we know, no specifications and few experiments exist for acquiring LiDAR data adapted to cadastral modeling of indoor and outdoor property units (Jamali et al., 2013; Hao, 2011; Souza and Amorim, 2012).

This new field of application of the LiDAR instrument is a motivating factor; it may represent a lucrative market for land surveyors and resellers. Is the LiDAR requirement the same for cadastral application and city building modelling? This study will try to

Table 1: Characteristics of the LiDAR used during the survey

	Site A	Site B
Instruments	Callidus CP3200	FARO Focus 3D[1]
Year of commercialisation	1997 to 2006	2010 to now
Spec Field of view (H:V)	360:140	360:305
Spec Distance range	32 m	130 m
Spec Precision (distance of 50 m.)	5 mm	2 mm
Survey resolution	2 to 20 cm between each points	2 to 20 cm between each points
Number of scans	15	18
Number of survey point cloud	1 680 000	24 350 000

[1] FARO Laser Scanner Laser Focus 3D is now traded by Trimble under the name Trimble TX5.

answer this question by examining the capabilities in comparison to traditional survey instrument with terrestrial LiDAR, for acquiring 3D spatial data required for the production of cadastral representation (2D plans and 3D models).

Study cases and methodology

The methodology consisted of using a terrestrial LiDAR (laser scanner) to survey two apartment buildings (co-ownership units), and comparing its capabilities with current survey instruments to produce 2D cadastral plans and 3D models. The features of interest are the boundaries of the 3D units, which are not visible (*fiat* objects) and consequently deduced from human opinion, and the presence of physical objects (*bona fide*); in the case of an apartment such physical objects may correspond to walls, ceilings, floors, stairs, etc.

The case studies are located in the province of Quebec, Canada, and correspond to a simple apartment structure composed of two levels with two co-owners (private and common parts). Table 1 shows some technical information for the LiDAR used. For the traditional survey, both sites were measured with a Distancemeter instrument (a portable laser rangefinder with a precision of 5 mm for a distance of 50 m). Callidus and Faro LiDAR instruments were selected mainly because they were available in our laboratory.

The focus of the study is not to compare one LiDAR technology to another, but the fitness for use of LiDAR acquisition approach (scanning instruments) compared to traditional survey instrument.

Figure 1 presents a picture of the two apartment buildings. Both sites refer to two co-owners and present two floors. Both sites were surveyed by Distancemeter and LiDAR instruments. Figure 2 shows for each site the 2D plans produced from LiDAR data (plans of site B were built by Groupe VSRB, http://www.groupevrsb.com/, a private firm collaborating with us). For site A, 10 indoor stations and 5 outdoor stations were scanned by the LiDAR, while for site B, 15 indoor stations and 3 outdoor stations were required. Objects to be scanned were walls, ceilings and floors. In total, site A needed 16 walls to be recorded while site B required 49 walls. To this, we collected and recorded the height of the ceilings and the altitude of the floors. Figure 3a shows an example of the points cloud for site A, while figure 3b presents the preliminary construction of the facade. Figure 4 shows an example

Figure 1: Two apartment buildings surveyed by the terrestrial LiDAR

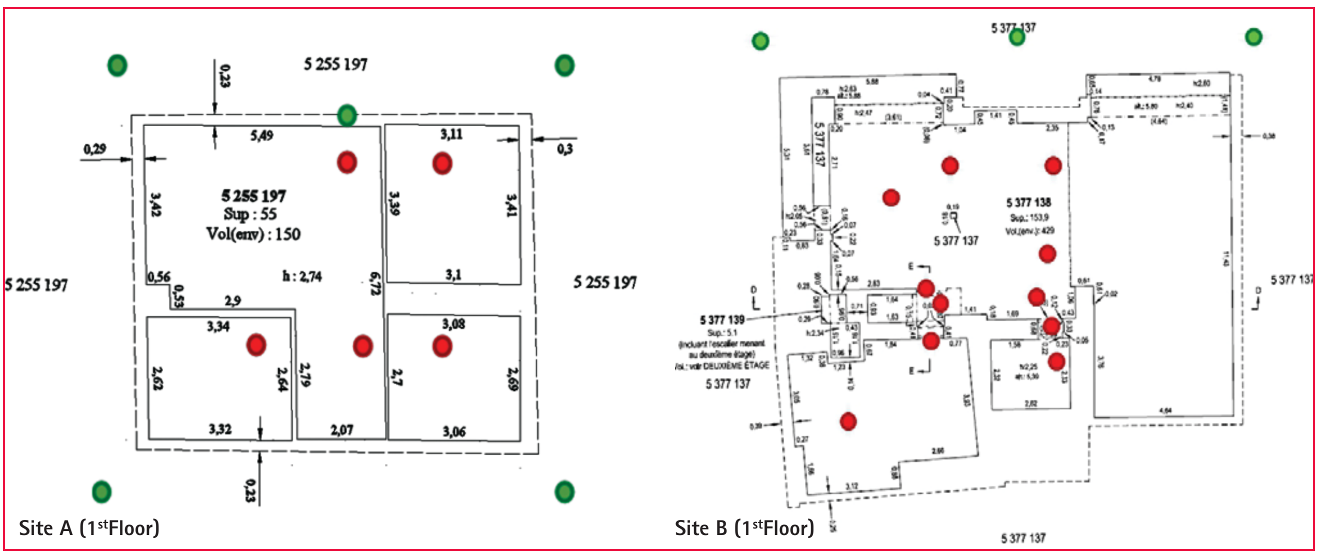

Figure 2: Examples of 2D maps produced from the LiDAR survey for the sites A and B (red dots =indoor stations, green dots=outdoor stations)

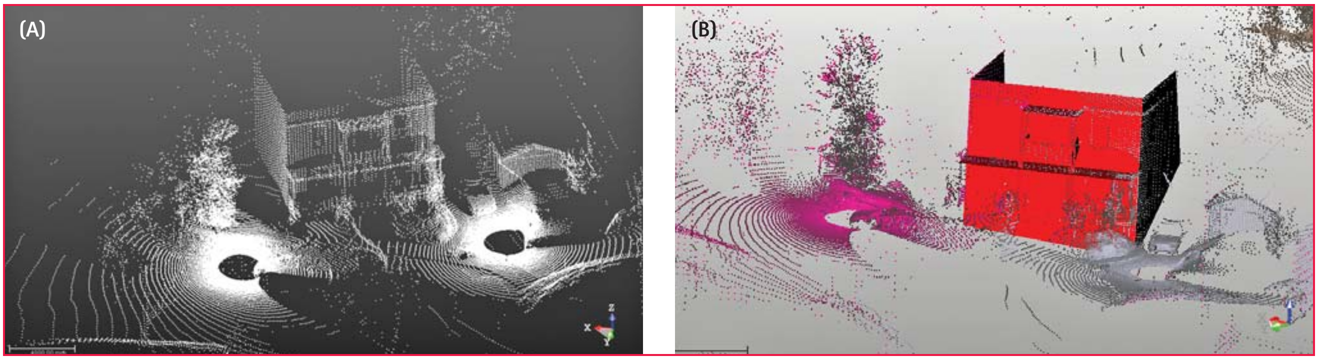

Figure 3: A) Example of LiDAR points cloud and B) the construction of the facade of the building

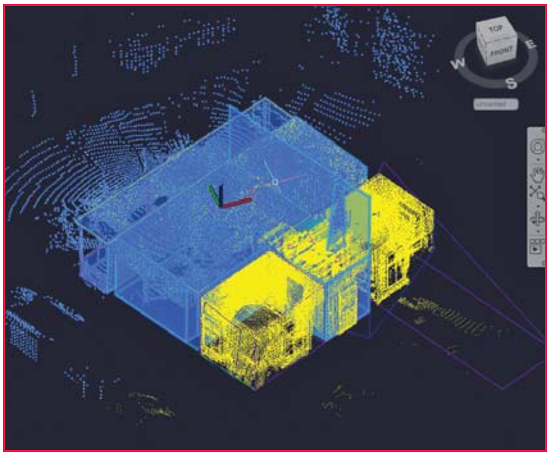

Figure 4: Example of inside scan assembling

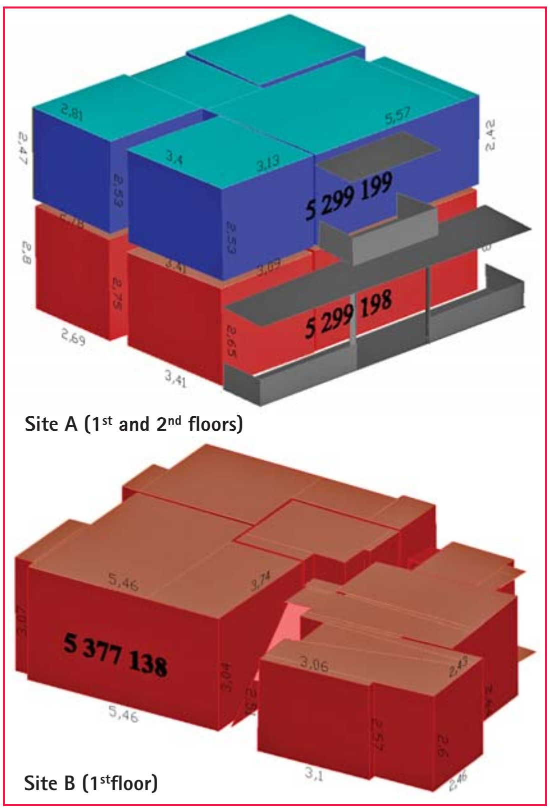

Figure 5: 3D models produced from terrestrial LiDAR for sites A and B

of inside scan assembling. Finally, figure 5 presents the 3D models produced from the LiDAR points (Trimble RealWorks for scan assembling and Autocad for map designing were used).

Comparison

To enable the comparison, a list of criteria was first established - some are related to the acquisition phase and others to the modelling steps. This list was verified with the land surveyor firm. The 2D plans and 3D cadastral models were produced from traditional spatial data collected by laser rangefinder (Distancemeter) and laser point cloud (LiDAR). Regular cartographic production and 3D modelling techniques and software were used. The 2D cadastral plans created from the Distancemeter were produced by a land surveyor firm (Groupe VRSB), and they respect the specifications of the Quebec Department of natural resources that is responsible for maintenance of the cadastral system. The graphic tolerance for the plans is 21 cm at a scale of 1,000. The rest including the 3D models were produced by the authors, respecting the same specifications.

Tables 2 and 3 present a subset of the results of the comparison made.

Discussion and conclusion

Some facts may be outlined from the comparison between the Distancemeter and LiDAR survey instruments. The survey duration of LiDAR instrument is slightly longer than Distancemeter. This result is dependent on scan speed, number of scans and the view angle per scan. The number of operators is also important to consider. For the Distancemeter, only one operator was required, while for the Callidus, two operators were necessary and one operator for the Faro. Data acquisition strategy may also be setup for LiDAR technology in order to reduce the survey duration and cost. For instance, not scanning the entire space but only specific objects related to the boundary of the 3D units was perceived as a valuable approach, but not experimented in the current tests. Overall, the acquisition phase is quite comparable between both instruments. Nevertheless, both instruments use distinctive mode of data acquisition. The LiDAR systems scan everything in the space while with the Distancemeter, the operator has to decide what objects are to be surveyed. For example, if the operator forgets to survey some objects, another survey will be required. This condition directly impacts the planning strategy for acquisition and modeling phases.

Regarding the modelling phase, the results show mixed conclusions. The production of 2D plans by Distancemeter clearly presents better results compared to LiDAR

Table 2: Comparison between Distancemeter and terrestrial LiDAR for cadastral data acquisition

	Distancemeter	LiDAR (Faro; Callidus)
Survey duration (*in hours*)	4h	4h ; 5.5h
Number of measures or scans	50	18 ; 15
Number of operators	1	1 ; 2

Table 3: Comparison between Distancemeter and terrestrial LiDAR for cadastral data modelling

	2D plan production		3D model production	
	Distancemeter	Faro; Callidus	Distancemeter	Faro; Callidus
Preprocessing time (Scan assembling)	1h	1h; 8h	1h	2h; 19h
Geometric modelling of all objects	4h	7h; 7h	5h	3h; 15h
Completeness (number of objects collected/required)	100% (49/49, 16/16)	100% (49/49); 160% (26/16)	125% (20/16)	150% (76/49) ; 400% (64/16)

technology while, it performs better for the production of 3D models compared to 2D plans. The main issue for LiDAR data processing is to determine the geometry of the object extracted from the numerous point clouds, while with Distancemeter, the geometry of the object is already known in the field (by the operator). This situation is easily explained by the distinctive mode of data acquisition of each instrument. The production of the 3D models took a longer time with the Distancemeter than with Faro data, but was faster compared to Callidus data. This situation is explained by the fact that no targets were used on site for the Callidus survey. Scan assembling and modelling of the objects were thus, more complex and time consuming when keeping the same production specifications. If we compare the completeness of the 3D models, it appears that the number of objects in the final product is higher for the point cloud compared to Distancemeter. Obviously, this situation is explained by the mode of data acquisition of LiDAR technology that collects all objects in the field of view, no matter if they are of interest. This aspect may be foreseen as an advantage of using LiDAR technology, specially when multi-usage of the 3D spatial data are planned (e.g., for urban planning or architectural projects).

Regarding the cost, they are estimated based on an operator's average salary, the survey or modeling duration and the instruments' rental fees (30$/day Distancemeter and 600$/day Faro). The training period was not considered (but could be part of this estimation). For the acquisition phase, we estimated the cost at 400$CDN for the Distancemeter and 1000$CDN for the Faro. For the modeling phase, 600$CDN was appraised for the Distancemeter and 800$ CDN for the Faro. Overall, not surprisingly, the cost for using Distancemeter was lower compared to LiDAR. Nevertheless, the difference is not considerable and yet should not be the only criteria to take into consideration when such needs arise.

Based on our experiment, it is currently difficult to draw conclusions about the distinctiveness of these results between surveying and modelling cadastral data compared to other kinds of objects, like city buildings. It is clear that for physical objects like walls and ceilings, the challenges are quite similar (scan resolution, scan assembling, obstruction, object reflectance, etc). Determination of the boundary of the 3D units (*fiat* objects) still remains as the result of the opinion of an expert. For traditional surveying, this opinion is somehow integrated with a field survey, as for LiDAR technology, this opinion may be estimated during data processing. This situation may have an important impact depending on who is doing the survey and the modeling phases. The number of objects to model and the geometric complexity of these objects are certainly some of the main criteria to take into consideration, when determining the advantages of LiDAR technology compared to traditional instruments. For instance, LiDAR point cloud offers the possibility of producing more detailed 3D model (i.e., containing not only cadastral limits).

> LiDAR technology offers interesting performance for surveying apartments and producing cadastral data. However our experiment only proposes preliminary results and has many limitations

In conclusion, we can state that LiDAR technology offers interesting performance for surveying apartments and producing cadastral data. However our experiment only proposes preliminary results and has many limitations. For instance, two apartment buildings are not sufficient to generate robust recommendations about better practices for LiDAR data acquisition and modelling. The selected apartment buildings were structurally quite simple (two levels) and did not allow us to fully address the complexity factor (geometric complexity of the object), which is probably a significant and distinctive criterion between both instruments. One of our future hypotheses to test would be: Higher is the geometric complexity of the building, better performance of LiDAR, and study sites will be selected to consider this factor. Overall, recent LiDAR technology like the Faro instrument obviously shows better results compared to older systems like the Callidus. Regarding the surveying of common or private parts (important factor for decision-makers like land tenure lawyers), no attention was paid to this end. We treated them as the same category of object. Further tests may integrate those important elements.

Acknowledgements

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A glance into the future of PNT

Munich Satellite Navigation Summit 2015

This year's Munich Satellite Navigation Summit took place on March 24 - 26, 2015 and was all about the future of PNT. 80 speakers from government, industry and science were invited by the organizing Institute of Space Technology and Space Applications (ISTA) of the Universitaet der Bundeswehr Muenchen to take a glance into the crystal ball.

Opening Ceremony – GNSS meets Jazz

The annual conference was kicked off on March 24 in the historical Court Church of All Saints with a ceremonial opening full of jazz sounds and discussions amongst high-level representatives from various European ministries and entities as well as from USA, Russia and China. About 400 participants from 20 nations were welcomed by the Deputy Bavarian Minister-President and Bavarian State Minister for Economic Affairs and the Media, Energy and Technology, Ilse Aigner, as well as Prof Dr Merith Niehuss, President of the Universitaet der Bundeswehr Muenchen, and Prof. Dr Bernd Eissfeller, chairman of the conference. Ilse Aigner pointed out that space science is an important matter for the Bavarian government, with over 50 entities being involved in the Aerospace sector. The following panel discussion of the evening was dedicated to the topic „Satellite Navigation and Space: International agencies discuss the status and future trends". All panel members underlined that the cooperation between the single systems is essential for a successful future of GNSS. In this context, Matthias Petschke, Director of the EU Satellite Navigation Programmes at the European Commission, remarked that Galileo will provide full service by 2020 and that it is important to create a multi-GNSS constellation with other providers, enhancing the international cooperation between the agencies. The need for cooperation to ensure compatibility and operability was also supported by Harold Martin, Director of the National Coordination Office for Space-Based Positioning, Navigation, and Timing in Washington, D.C., who furthermore pointed out that GPS is continuously improved and that there is a need to establish an U.S. coverage for GPS outage due to natural or man-made interference. He further explained that several alternatives are identified and assessed and that the decision is likely to be made in summer 2015.

Varied program on future of PNT

The conference program continued on the following two days with a broad overview on different up-to-date topics in the sector of PNT. Starting with sessions on the global, regional and augmentation satellite navigation systems, the program focused amongst others on issues like the future trends of PNT and the GNSS (Application) Market, the role of GNSS and space sensors in "Big Data" or the processor and semiconductor trends for GNSS receivers. One session, chaired by Prof Dr Michael Meurer from the German Aerospace Center (DLR), dealt with the subject "Alternative Positioning, Navigation, and Timing (APNT)". Due to the vulnerability of GNSS to interference and due to the dependency on a single system, the strengths and weaknesses of various alternative PNT systems were discussed by the panellists that came from different sectors like maritime and aviation. Prof Dr Wouter Pelgrum, Ohio University, stated that APNT should be a combination of systems that will enhance the GNSS performance, depending on the application. From his point of view eLoran could be a plausible way due to the high power of the signal - that makes it difficult to jam - as well as the high accuracy. Dr Nick Ward from the Research & Radio Navigation Directorate at the General Lighthouse Authorities talked about PNT in maritime services. He said that GPS has become the normal means for maritime PNT, but added that eLoran should provide additional support based on its accuracy. According to Dr Ward, the situation of eLoran in Europe shows that there is not a coordinated policy on resilient PNT and that the future challenge will be to find a continuous commitment to the system, at least during the next 10 years.

The conference program was completed by an exhibition, at which 15 companies and institutions presented their business and products.

The Munich Satellite Navigation Summit 2016 will take place on March 01 - 03, 2016.

- Kristina Kudlich

Opening Panel members from left to right: Prof Dr Bernd Eissfeller, Carlo des Dorides, Prof Dr Volker Liebig, Matthias Petschke, Harold Martin, Jianyu Chen, Jean-Yves Le Gall, Mikhail Khailov

JAVAD

In the Issue:

Precision with TRIUMPH-LS

Produce reliable and accurate transformation parameters for a local set of known positions.

Visual Stake Out

If your goal is to set stakes, this is simply the worlds' fastest, and least fatiguing method.

Camera Features

Offset Survey, Visual Angle Measurement and more with Triumph-LS

Field Report

We have been testing the JAVAD equipment lately. The receiver we used is the Triumph-LS which has the receiver and data collector incorporated into one unit with a battery life of 30 hours. It utilizes all the current satellite systems, is designed to incorporate additional systems when they become available. It comes with a lifetime offer of software upgrades. The main reason we offered to test it was to see if it would produce better results under canopy than our present equipment and IT DID. It utilizes over 800 channels and 6 engines and an auto-verification system that will guarantee the results if you follow the guidelines. If fact, if you can prove you got a bad fix, they will pay you $10,000. Cameras are incorporated in the unit. The software programs have lots of useful tools and their customer service was very good. They are very open to suggestions for improvements or changes to the software and very efficient at incorporating beneficial recommendations. We are considering ordering units for all our surveyors if affordable.

One important thing we learned while testing the equipment: If you are using a VRS signal when you are working in areas with lots of tree cover and getting lots of multipath signals when trying to get fixed RTK results, you will get better results if you set up your base nearby and use the base instead of VRS (that applies to all brands). And with the JAVAD equipment you may get additional satellites.

The JAVAD equipment is also much-much less expensive that other brands, has tilt compensation, has a collapsible rover rod, has a touch screen with an alternate touch pen in case you don't want to use your fingers and the entire unit is much more compact so it takes up much less space in your vehicle.

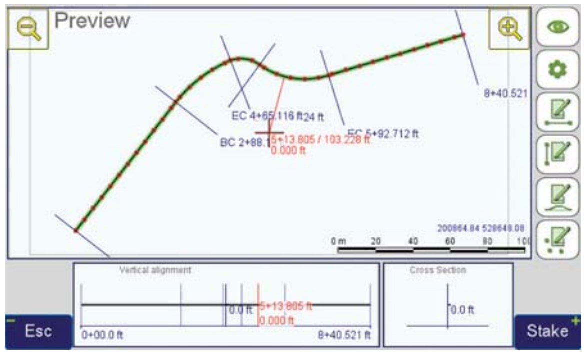
I have always dreamed of the "black box" that would give you accurate location coordinates no matter where you are. The JAVAD equipment is the next step.

Gary Kratz
Regional Land Surveyor
US Fish and Wildlife Service

Visual Stake Out

Visual Stake Out, which we often refer to as VSO, is a J-Field exclusive, and is made possible only due to the complete integration of the wide array of sensors built into the Triumph LS. The actual uses of Visual Stake Out are as varied as the work we do. If your goal is to set stakes, this is simply the worlds' fastest, and least fatiguing method. To access VSO at any time while staking, simply press the GUIDE button.

Animated Aerial View

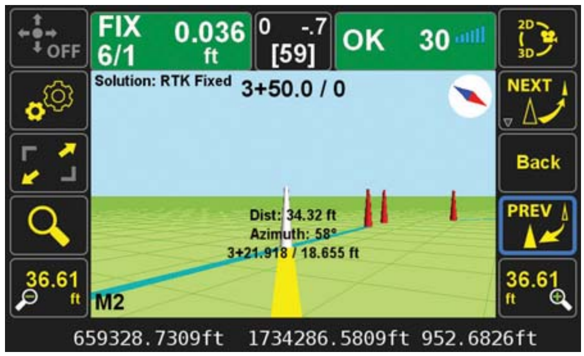


When you select the GUIDE button. There are three optional screen views that you may choose from by pressing the top right button. Two of which are forward facing, one being an animated synthetic landscape view, and one with live video from the forward facing camera. Also included is an animated aerial view, which is very nice for the stakeout of lines, and viewing the overall task.

This reviewing surveyors personal VSO preference is the animated synthetic landscape view. In this view, you will have arrows on the screen telling you which direction to face.

Once you are generally aimed in the correct direction, you will see a yellow line on the screen indicating the direction to walk. All that you have to do is follow it.

Animated Synthetic View

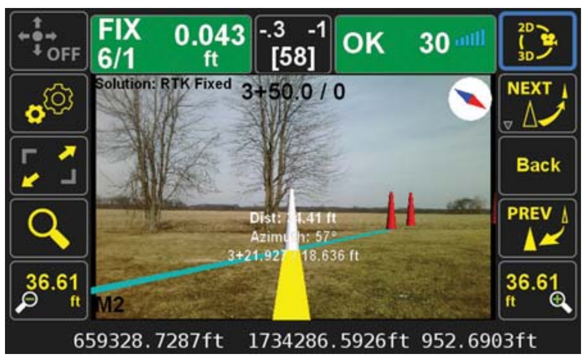


When you are approaching your destination, you will see that a simulated traffic cone is at the end of the yellow line.

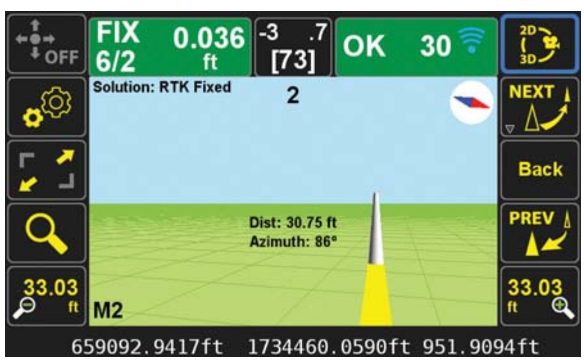
Because the screen update rate is so incredibly fast and smooth, you can simply stick your survey pole into the cone, and the cone fills the screen. Using this method will get you within about 2 tenths of a foot all day long, all without ever looking at a numerical value on a display.

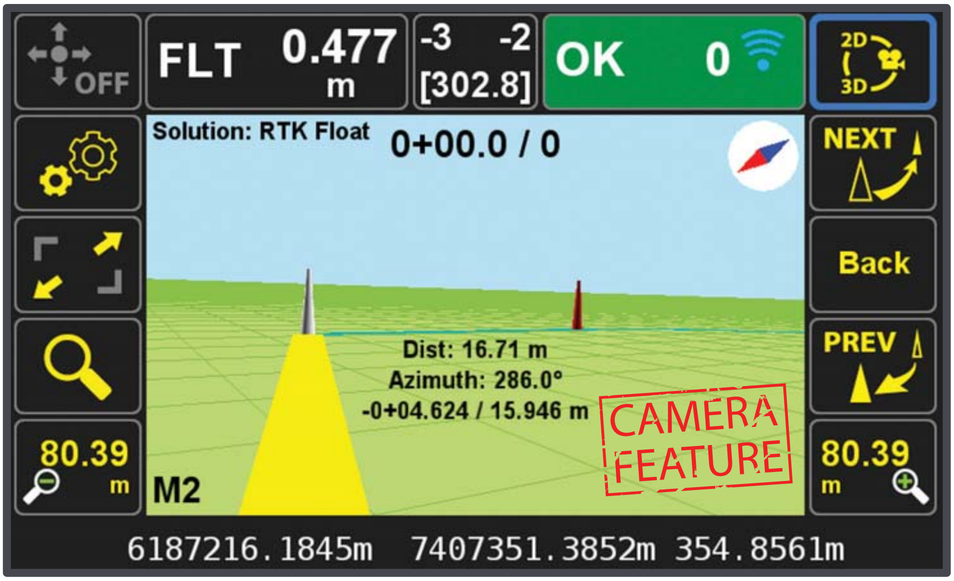
At this point, when you press the back button, you will be at the normal stakeout screen, where you have the information to make your fine adjustment.

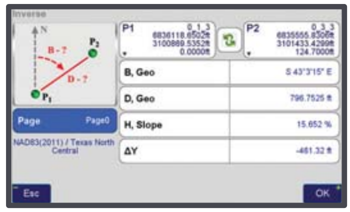
Live Video

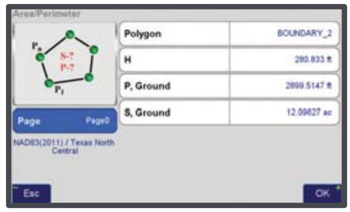


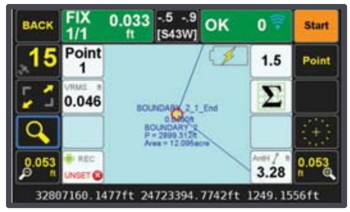
For a surveyor performing stakeout work, the surveyor is relieved of the constant monitoring of In/Out Left Right, or North and East numerical information normally provided by a data collector. This leaves much more mental energy to devote to the other aspects of the job at hand. If a surveyor is working solo, and carrying their own lath bag, hammer, and survey pole, being able to walk to the exact spot the stake goes, without ever having to actually stop and read any numbers is priceless. In addition, it is worth

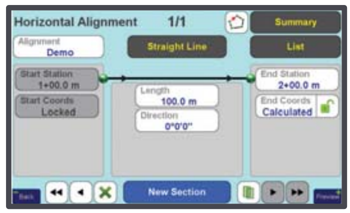












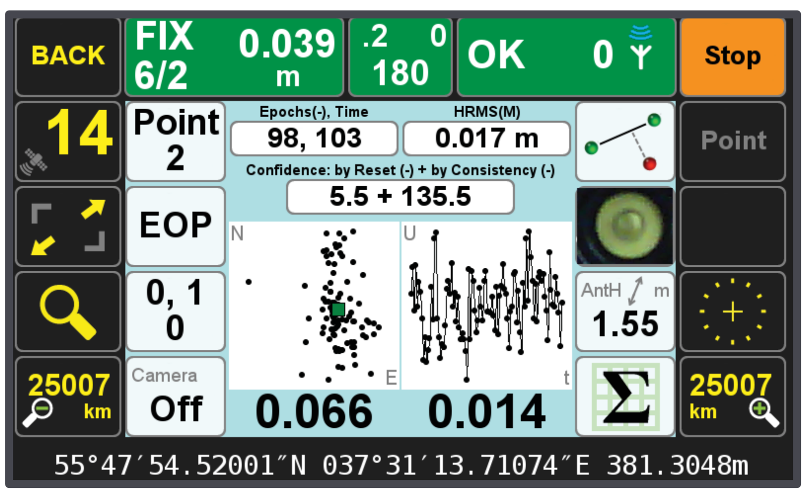
Store and Stake

Introducing GUIDE data collection in the TRIUMPH-LS. Visual Stake-out, navigation, six parallel RTK engines, over 3,000 coordinate conversions, advanced CoGo features, rich attribute tagging on a high resolution, large, bright 800x480 pixel display.
Versatile attribute tagging, feature coding and automatic photo and voice documentation.
The TRIUMPH-LS automatically updates all firmware when connected to a Wi-Fi internet connection.

View and Document your level

The downward camera of TRIUMPH-LS scans and finds the liquid bubble level mounted on the pole. Then focuses on the circular bubble automatically and shows its image on one of the eight white buttons of the Action Screen. You can:

- View the liquid bubble level on the screen.
- Document survey details including the leveling by taking automatic screen shots of the Action Screen, as shown here.
- Calibrate the electronic level of TRIUMPH-LS with the liquid bubble level for use in Lift and Tilt and automatic tilt corrections.



All these camera features are possible only in TRIUMPH-LS where camera, and GNSS antenna are co-located and all other modules integrated.

Precision with TRIUMPH-LS

Our friend from Javad GNSS, Michael Glutting, recently related that a surveyor in Minnesota asked how he could use his Triumph-LS and corrections from the MnCORS real time network to accurately work within his projects previously established with HARN. The MnDOT provides mount points for various adjustments of NAD83, however, a surveyor can quickly produce reliable, highly accurate transformation parameters for a local set of known positions as this paper describes.

In 2000, Stanger Surveying of Tyler, Texas, established a GPS control network consisting of 30 monuments for my hometown of Kilgore, Texas, over an area measuring about 7 miles square (50 square miles). Even after 15 years, the network proves to be incredibly accurate and was well constructed with ties to two different HARN PACS (High Accuracy Reference Network Primary Airport Control Stations) and multiple repeat and braced vectors. This network predated the modern proliferation of CORS stations, and so there is no precise relation to the CORS and therefore no precise relationship to NAD83_2011. This means that there is some unknown translation from the Kilgore GPS Control Network of 2000 and NAD83_2011. Because of this, we must resolve these transformation values by observation.

To do this, we conducted two field campaigns. In both sessions, I placed a Javad GNSS receiver on a stable monument, POST, located at our office. The first session, I used a Triumph-1, and for the second, I used a Triumph-2, both broadcasting corrections over the Internet via TCP. The NAD83_2011 position of POST has been accurately determined by hundreds of hours of data from several different GPS receivers processed through OPUS.

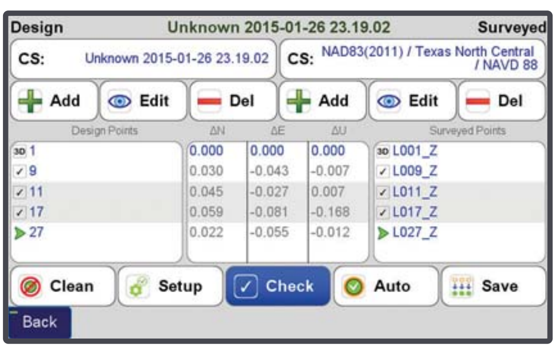
In the first session, my father, J.D., and I observed five different monuments from the Kilgore network with the Triumph-LS for 90-120 seconds each. These points were the primary control Stanger established from the HARN PACS. After observing those five points I performed a preliminary localization.

In this preliminary localization, I fixed only one point (point L011_A). Three of the remaining four show very low residuals, however point L017_A, with its noticeably higher vertical residual suggests this point has been displaced since it was established in 2000, or that there is an error in the observation itself - only a repeat occupation will tell.

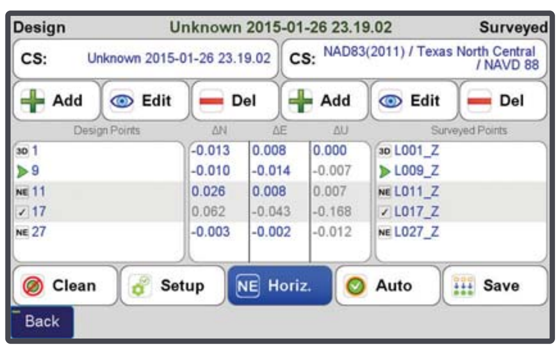
During the second session, we observed the five points again and used the average tool in J-Field to perform a weighted average of the two points. The second observations showed excellent agreement with the first observations. This chart shows the difference in the repeat observations for each of the five stations:

STATION	Base-Rover Vector Length (usft)	Δ 2D (usft)	Δ UP (usft)
L001	37342.3	0.097	-0.029
L009	23155.7	0.048	-0.139
L011	13559.4	0.049	-0.005
L017	24184.6	0.036	0.033
L027	2285.9	0.032	-0.005

With the five control points averaged, I began the localization process again. First I performed a minimally constrained localization holding only point L001. Notice that point L017 still appears to be an outlier.



Next, I constrained horizontally to L001, L009, L011 and L027 while still only fixing point L001 vertically. The residuals predictably decrease among the points fixed.



With the residuals indicating a good fit, I turn my attention to the parameters of the localization.

From these parameters, several observations can be made immediately. Because both surveys relied upon the same definition of North, it is expected that there would be little, or no rotation. Furthermore, because both surveys relied upon the same definition of the foot, US Survey foot measured along the same grid surface, Texas Coordinate System of 1983, North Central Zone, there should be little difference in the scale factor. The rotation determined is less than half of one arc second and the scale factor being applied to best fit my survey to Stanger's original work is only 1 part-per-million, revealing very good relative agreement between the surveys.

Finally, I am ready to perform a fully constrained localization, holding all four points (still disregarding the displaced monument L017) both horizontal and vertical.

I set both the rotation and scale to zero as I do not want to redefine North nor the US Survey Foot. Now that more than one point is involved vertically, a tilted plane is calculated. Because the Stanger survey was based on Geoid96 and today's survey is based on Geoid12A, I left the tilt values intact. In this case the inclination values are so small as to be practically insignificant.

The final results indicate that the translation between the Kilgore GPS Control Network of 2000 and NAD83_2011, epoch 2010, (usft) is N: -0.0497 E: +0.1188 U: -0.0587. From this point forward, I can use this new localization system to survey in coordinates related to the Kilgore GPS Control Network of 2000 with a reference station broadcasting NAD83_2011 corrections, or I can transform coordinates from surveys related to the Kilgore GPS Control Network of 2000 to NAD83_2011.

The final step in this exercise is to use this transformation to test on known points. In order to do this, we observed five additional points from the Kilgore network that were not used in the localization. Each point was observed for 120 seconds with the Triumph-LS with corrections from the Triumph-2 onPOST. The chart below depicts the difference in coordinates determined from the LS using the localization and the original Kilgore GPS Control Network of 2000 coordinates.

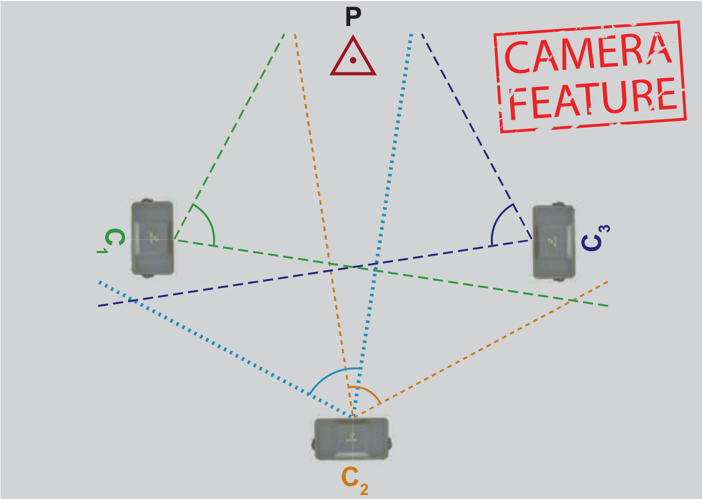
These residuals can be attributed to several different sources: original survey error, current survey error, displacement over 15 years, as well as errors in the localization/transformation being used. However these results, together with the residuals from the localization, indicate that the localization, as determined, will allow me to reproduce the Kilgore GPS Control Network of 2000 coordinates within a centimeter, anywhere within the network. The total time required to perform this exercise was 4.5 hours in the field (including redundant observations) and 30 minutes of calculations, which were all made within the Triumph-LS.

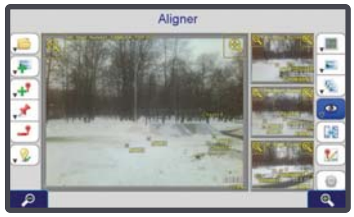
Shawn Billings, PLS

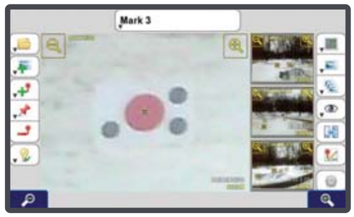
Station	Base-Rover Vector Length (usft)	2D Residual (usft)	Up Residual (usft)
L007	15363.3	0.036	-0.006
L012	14416.1	0.030	0.101
L019	12900.9	0.025	0.001
L021	7553.0	0.048	0.121
L025	11238.8	0.011	0.048

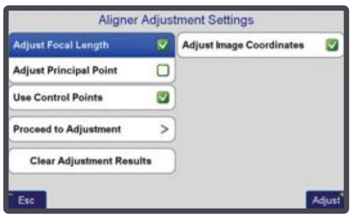
Offset Survey with built in camera

You can survey points with internal TRIUMPH-LS camera with accuracy of about 2 cm. Take pictures from at least three points. Leave a flag on points that you take pictures from, otherwise accuracy will be about 10 cm.







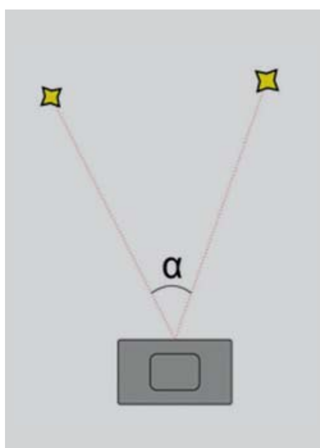


Visual Angle Measurement with Triumph-LS

The new Visual Angle Measurement function of the TRIUMPH-LS allows measuring angles between points by using photos taken by the TRIUMPH-LS camera and use in CoGo tasks with the Accuracy of about 10 angular minutes.

To measure an angle:

- just take an image containing both objects of interest and open it in the Measure Angle screen
- select first and second point (using zoom to focus on necessary features)
- The angle between points is immediately displayed on the screen.



noting that if you are looking down at a data collector screen, reading numbers to navigate to your point, you will find the VSO method to be much safer when you find yourself surrounded by construction equipment, and you can actually keep your head up.

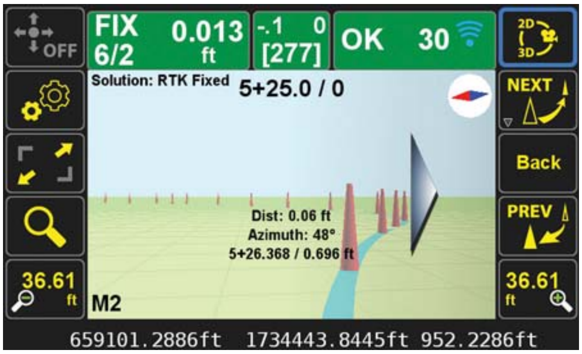
If you are staking out an alignment, the alignment will be depicted as a light blue line on the ground, and any endpoints, and interval points which have been specified will be depicted by the familiar traffic cones. The point you are currently staking will be depicted with a silver colored cone, and the points not yet staked will be depicted as orange traffic cones. This is as close to cheating as any surveyor should ever get

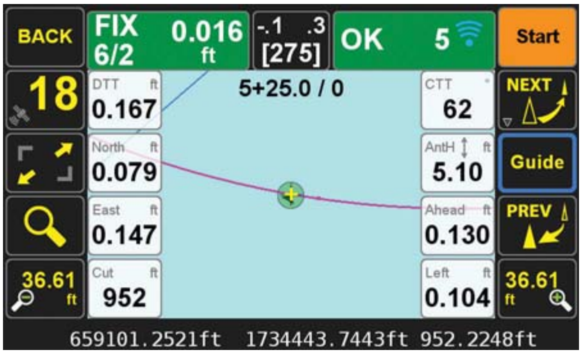
When you are performing boundary work, VSO can be one of your best friends. It will point right to what you are looking for. This is where the video overlay can be very useful, it will answer the questions of which side of the tree would be the best to start clearing with a machete, and is the point we are looking for on the other side of the stream?

I have also found that the video overlay of GUIDE is also a useful method of verifying the internal compass calibration. As an example, when you stake out the point number of your base station, you should find it hiding right behind a traffic cone.

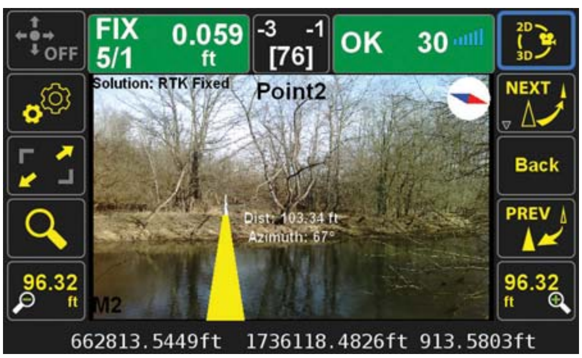
When you are within 10 feet of the target point, the traffic cone becomes transparent.

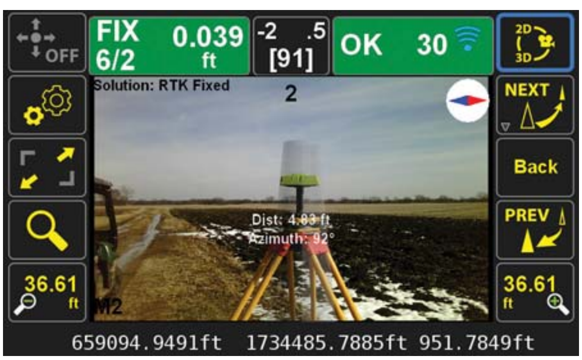
This is a feature that must be seen, and used to be believed. Until you do, please just trust me.





Stake Numerical Indicators Surrounding Map View





Semitransparent Cone Symbol Over a Point

Javad Ashjaee (left), John Evers and Shawn Billings.

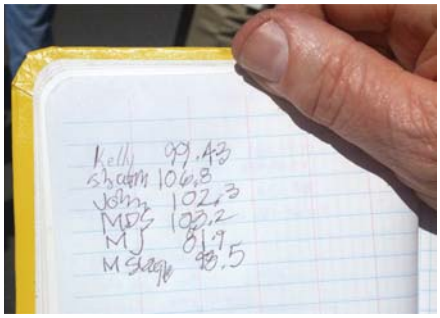
John Evers
Professional Surveyor, Ohio 7869

John Nailed It!

During a week of advanced training for Javad's 5PLS Support Team in San Jose, California, which covered topics such as Live Support over RAMS (Remote Access and Monitoring Server) for Triumph-LS users, Localizations, Linework Collection, Import and Export, Staking, Base/Rover Setup, DPOS processing, and exploration of many other features and future software enhancements, the team took a brief time out for a competition any surveyor would appreciate - a pacing contest.

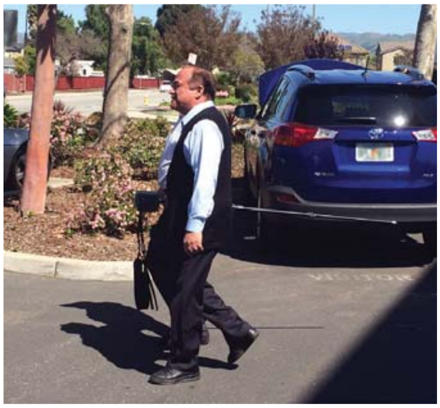
Inverse between start and finish lines.

Michael Glutting used a Triumph-LS, receiving corrections from an Internet base mounted to the Javad facility's roof, to precisely determine a distance between two marks in the parking lot. The result was 102.31 US Survey Feet.



Yep, that's a real field book with hand written data!

Each member of the team then evaluated the baseline, and made careful effort to count their strides as they paced, one at a time, across the parking lot. Each submitted their measurement to the official record keeper, Kelly Bellis.



Doug Carter attempts to avoid detection by concealing himself behind an innocent pedestrian in this photographic evidence of his illegal use of pacing enhancements.

Unfortunately one contestant was disqualified for violating the International Federation of Pacing Official Rules and Guidelines by attempting to use pacing enhancements during the competition.

Once the dust had settled, the results were tabulated and compared to the precisely determined baseline distance. The winner, with an impressive 102.3 feet, was John Evers, Professional Surveyor from Ohio. John's submission varied only one hundredth of a foot from the RTK derived distance - a ratio of error of more than 1:10,000.

Runner-up Matt Sibole of Kentucky, submitted a very respectable distance of 103.2 feet - a difference of 0.89 foot.

At the conclusion of the event, the team celebrated the diverse skills required to be a surveyor - including the use of advanced, modern measuring technologies tempered with ancient techniques requiring nothing more than an even stride. Congratulations, John!

Story by Shawn Billings. Photographs by Nedda Ashjaee.

Matt Sibole in motion while Doug Carter and Matt Slagle discuss pacing strategies in the distance.

Studies on revitalized GLONASS from India

This paper presents the potentials of using revitalized GLONASS from India as an active alternative to GPS and as a component for Multi-GNSS. Presented results on GLONASS accuracy, visibility, satellite geometry and signal strengths are obtained using data collected over long periods of time from different parts of India

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Introduction

Global Navigation Satellite System (GNSS) is now becoming increasingly popular because of its several advantages. Along with the operating GPS, revitalized GLONASS was declared fully operational since 2011 end[1] and worldwide efforts were noticed for developing similar new global and regional systems and a new term 'Multi-GNSS' was coined by the GNSS community to describe the situation. Efforts from India during the late 90s showed the benefits of GLONASS in a stand-alone and in integrated modes of operation with GPS [2]. Therefore, it is interesting to study revitalized GLONASS again. This paper presents the results on capabilities of GLONASS from India, based on long-term data using two types of GNSS receivers with special emphasis on GLONASS-based low-cost, single-frequency and stand-alone GNSS solutions. The discussion is subdivided into two parts- brief discussion on GLONASS modernization evolution and study results underlining the utility and advantages of presence of GLONASS respectively. The paper is expected to provide a general impression on the advantages of GLOANSS from India in its post-2011 revitalized form.

GLONASS modernization and current constellation status

After successful operation of GLONASS during the 1990s [2], the system became unusable since the beginning of 2000 due to non-replenishment of satellites. A GLONASS revitalization plan was declared by the Russian authorities in 2004 [3] and accordingly, 40 GLONASS satellites were launched between December 2004 and December 2014. As of mid-April 2015, there are 28 GLONASS satellites in the fleet - 24 fully operational, 1 Spare, 2 in Flight Testing phase and 1 under check, populating each of the three GLONASS orbits with 8 operating satellites that are launched in or after December 2006 and have been operating since early 2007. Latest operating GLONASS satellite was launched on March 24, 2014 (#754), while the last one launched on December 1, 2014 (# 702) is in Spare state. The revitalization process of GLONASS has been studied by us [4, 5] and a stable constellation is observed over the last 3½ years. Therefore, studies on the usability of GLONASS from India have been taken up. This would help in understanding the potential of GLONASS for the stakeholders with regard to its mass-market applications and in increasing confidence among its users.

Data collection plan and experimental set up

To study GLONASS capabilities from India, GNSS (GPS, GLONASS and GPS+GLONASS (MIX)) data using L1 C/A was monitored during 2012 - 2014 from a fixed location, Burdwan, marked as '1' in Figure 2 using two GNSS receivers- Rx #1 and Rx #2. Data from few other points scattered over the country were also collected using Rx #1 for 3-4 days during August – November, 2012. Data monitoring points are shown and described in Figure 1 and Table 2 respectively, and brief hardware and software descriptions are presented in Table 1. General experimental set-up for

Table 1: Experimental set-up brief description

Receiver Designator	Brief Hardware Description	Data Collection Software	Collected data format, Data Rate
Rx #1	GoeS-1M OEM Board, Single Frequency, 24 Channel, generic low-cost GNSS antenna	Developed in house	National Marine Electronics Association (NMEA) 0183, 1 Hz
Rx #2	Javad DELTA G3T, Multi-Frequency, 216 Channel, dynamic GLONASS calibration, GrAnt G3T Antenna with multipath reduction	Javad NetView®	

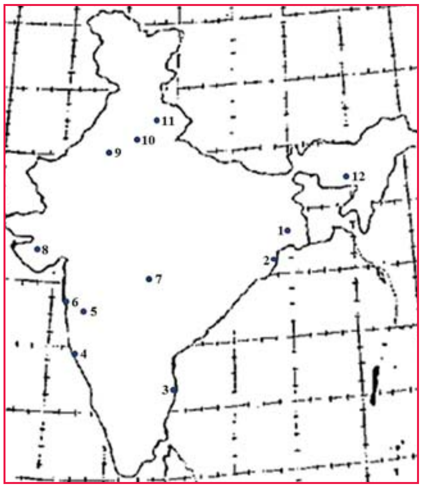


Figure 1: GNSS data monitoring locations in India

Table 2: GLONASS data monitoring points and GLONASS availability in India

Location	Location Id (LId) (Fig 1)	Satellites in View			Satellites used		
		Max	Min	Avg	Max	Min	Avg
Burdwan	01	12	05	8.41	11	03	7.38
Balasore	02	12	08	9.45	11	06	8.57
Chennai	03	11	06	8.57	10	04	7.25
Goa	04	11	06	8.46	09	04	5.47
Pune	05	10	05	8.08	08	03	5.33
Panvel	06	11	06	7.69	09	04	6.19
Nagpur	07	11	05	8.81	10	05	7.48
Rajkot	08	11	05	8.79	11	05	7.83
Pilani	09	11	05	8.34	10	04	7.15
Noida	10	12	05	8.05	10	04	6.92
Dehradun	11	12	09	10.09	11	07	8.79
Shillong	12	12	07	8.21	10	04	8.09

data collection consisted of the GNSS receiver, PC and external rooftop mounted GNSS antenna. Useful data extracted from the recorded NMEA data stream include date, time, navigation solutions, DOP values and information about all used satellites for each observation.

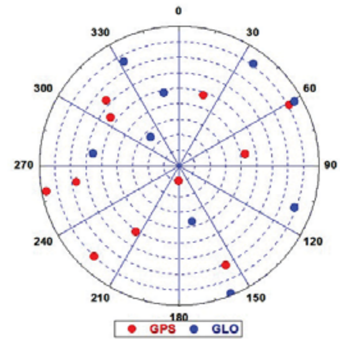
Results and discussions

GLONASS satellite signal availability

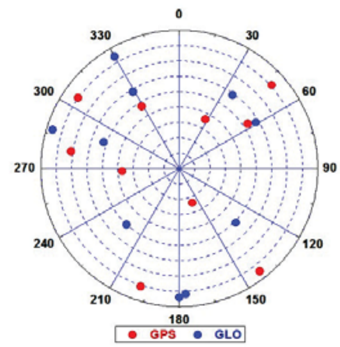
Results of the study on GLONASS signal availability from India is presented in Table 2 that shows the number of GLONASS satellites in view and in use for solution from different data monitoring points. It is observed, except for a transient period of time at two locations (LId #1 and #5), 4 or more GLONASS satellites are available for use. Maximum of 8 to 11 GLONASS satellites are available for use above 5^0 elevation. The table also shows that on an average, simultaneously 7 or more GLONASS satellites are visible from any part of India, of which 5 or more are used for the solution. The results strongly endorse the usability of GLONASS to provide stand-alone position solution as an active alternative to GPS.

GLONASS satellite distribution and limited visibility conditions

Presence of GLONASS with GPS is expected to provide more number of usable satellites. 'Skyplots' are presented in Figure 2 using data from two locations; here the elevation angles are shown radially with the centers indicating zenith, and the azimuth angle is shown along the circumferences with top of the figure indicating North. The figures indicate, as expected, that larger number of GNSS satellites are visible in each quadrant of the sky. The situation is useful for system independence and redundancy, providing a better Signal in Space (SiS) scenario, in mitigating atmospheric effects in GNSS solutions which is a vital issue for Indian and other equatorial regions [6], and it may benefit the atmospheric research efforts.



Nagpur (LId #07) (07/09/2012; 13:55:24 IST) using Rx #1



Burdwan (LId#01) (02/01/2015; 13:10:32 IST) using Rx #2

Figure 2: GPS and GLONASS satellite distribution over sky

It is found that in limited GPS satellite visibility conditions due to obstructions (urban canyons or deep foliage), GLONASS satellites may augment the situation. Results of such a study with intentional elevation angle masks are shown in Table 3. Here the elevation cut-off angle for satellites is intentionally increased to 30^0 and 45^0 to simulate a canyon-like environment and the receiver

Table 3: GNSS satellite usability with high cut-off elevation angle

Elevation Mask (deg)	Location (LId#)	GPS sats in use (Total usable above 5^0elevation)	GLONASS sats in use (Total usable above 5^0elevation)
30	Chennai (03)	5 (12)	4 (9)
	Balasore (02)	5 (13)	4 (6)
	Pilani (09)	5 (10)	4 (9)
	Burdwan (01)	5 (9)	5(9)
45	Chennai (03)	3 (13)	2 (10)
	Balasore (02)	2 (12)	4 (9)
	Dehradun (11)	3 (12)	3 (9)
	Burdwan (01)	3 (9)	1 (8)

Table 4: GLONASS 2d and 3d error distribution

Cumulative error percentage	2d and 3d Error value lie within, m	
	2d	3d
100%	40	40
90%	15	35
50%	5	13

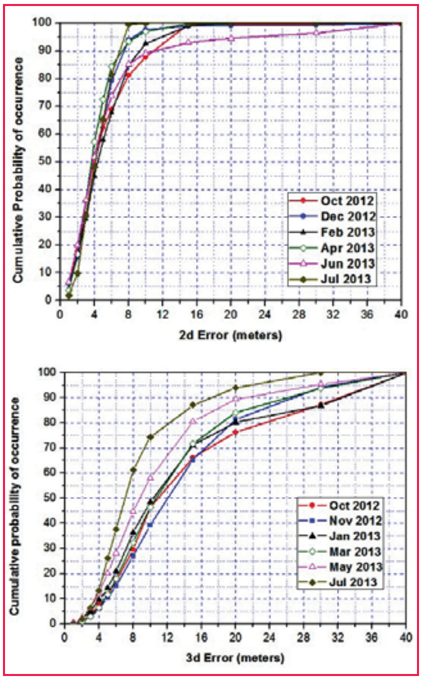


Figure 3: GLONASS 2d and 3d position solution error distribution (Rx #1, LId # 1)

is operated in MIX (GPS+GLONASS) mode. It is seen that, for a 45^0 elevation mask, requirement of four satellites for 3D solution is fulfilled using using both the systems together. For these situations, MIX-mode may help in uninterrupted navigation fixes.

GLONASS solution accuracy

Solution accuracy with stand-alone GLONASS

An important aspect of understanding GLONASS utility is to analyze the achievable accuracy. We analyzed short and long-term solution accuracy obtained using all-in-view GLONASS C/A L1 signal without augmentation or correction inputs. Initial results suggest higher variation of North errors over East errors. For detailed analysis, errors for individual solutions w.r.t. to a reference point are calculated. Reference points for both GNSS antennas (for Rx #1 and Rx #2) at Burdwan (LId #1) are calculated using long-time GPS-only solutions; the average values are taken as the reference latitude (La_0), longitude (Lt_0) and altitude (h_0) for each individual antenna [1]. Errors in 3 Dimension (3D) and 2 Dimension (2D) in meters for individual solutions w.r.t. the reference were calculated using the following equations. Here that 1 minute of arc of the earth curvature is assumed to be equivalent to 1852 m,

$$Error_{3d} = \sqrt{\Delta h^2 + (1852 . \Delta Lt . \cos(La_0))^2 + (1852 . \Delta La)^2} \quad (1)$$

$$Error_{2d} = \sqrt{(1852 . \Delta Lt . \cos(La_0))^2 + (1852 . \Delta La)^2} \quad (2)$$

where $Error_{3d}$ and $Error_{2d}$ are errors in 3 Dimension and 2 Dimension of the instantaneous solution w.r.t the reference respectively.

ΔLt is the difference between instantaneous and reference longitude values, ΔLa is for latitude values in minute of arc and Δh is difference for height in m.

For comprehensive analysis, GLONASS-only data collected over a month (say January 2012) are combined and analyzed. It is seen from data collected for few months using Rx #1 that average 2D GLONASS (horizontal) error remains within 10 m, while 3D errors lie within 20 m. Here, we are trying to present the GLONASS solution capability using stand-alone, single frequency and low-cost GLONASS receivers. Therefore, more analysis using data from Rx #1 are presented.

Average errors for a month hardly provide information about the distribution of error ranges, and therefore, a different approach is adopted. 2D and 3D errors for all measurements for a month are subdivided into several 'error range bins'. Variable widths for the 'bins' are taken for different error-ranges. For a month, number of samples falling in a particular bin and percentage of occurrence in the bin is obtained considering the total number of samples for the month. Cumulative percentage of occurrence for a bin is calculated by adding all occurrence values in same and higher error bins. Obtained results are shown against the higher class boundary of the concerned 'bin'. Distribution of error values for achievable 2D and 3D accuracies of GLONASS solutions for few months are shown in Figure 3 for Rx #1. Summary of the results obtained from Figure 3 are presented in Table 4.

Solution accuracy of GLONASS in Multi-GNSS

In a developing Multi-GNSS scenario with fully operating GLONASS, it is interesting to study the effects and possible benefits of combining GLONASS with existing GPS from India.

To see the effect of GLONASS in a MIX-mode operation, a study was made using receiver Rx #2 on May 27, 2014. Increasing GLONASS signals (01 to 05) were used sequentially with 4 GPS for MIX solution and data for 10 to 20 minutes, as available, were collected for each combination. Average 2D and 3D

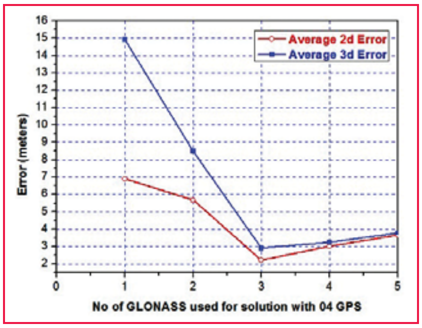


Figure 4: Effect of introducing increasing number of GLONASS in solution with 04 GPS

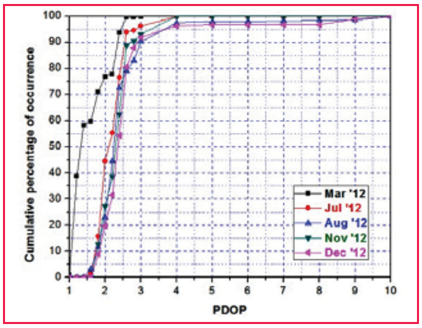


Figure 6: Cumulative PDOP distribution for GLONASS for different months (Rx #1, Lld #1))

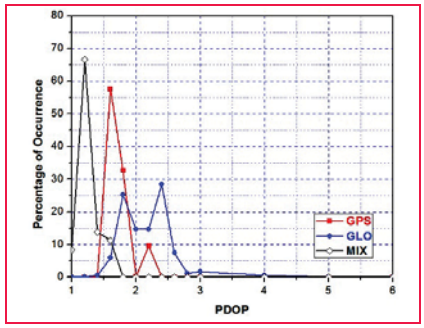


Figure 8: PDOP distribution for different GNSS modes (September, 2012, Rx #1, Lld #1)

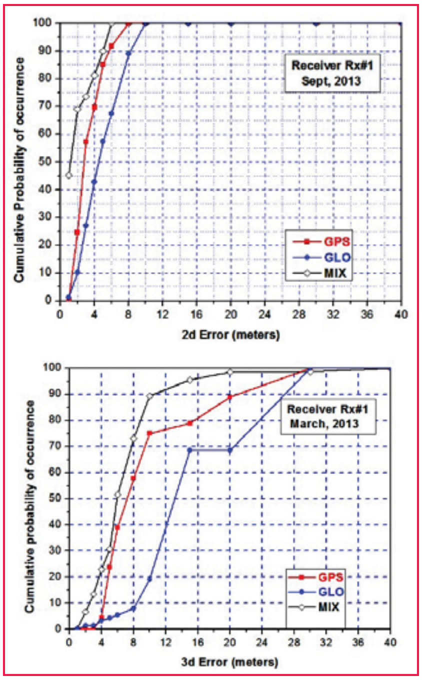


Figure 5: Comparison of GNSS errors (Rx #1)

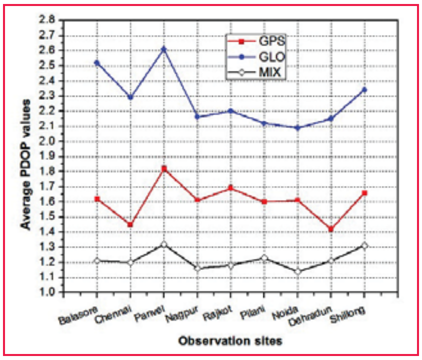


Figure 7: Average PDOP comparisonfrom different Indian locations (Rx #1)

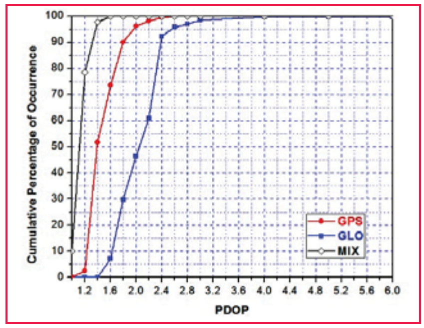


Figure 9: Cumulative PDOP distribution for different GNSS modes (February, 2012, Rx #1, Lld #1)

error values for the combinations were calculated using equations (1) and (2) and the results are shown in Figure 4. It may be noticed that increasing number of GLONASS contributes proportionally for enhancement of achievable accuracy in MIX mode that forms the basis of understanding the contribution of GLONASS in a Multi-GNSS operation.

Next study compares 2D and 3D accuracies of single and multimode GNSS operations. GPS, GLONASS and MIX data collected for different months were analyzed following the same procedure used earlier to calculate cumulative position error percentage for a specific error range. Sample data for two months using Rx #1 is shown in Figure 5. Inspection of the graphs reveals that both 2D and 3D errors in GLONASS were higher than those for GPS and MIX mode provides the lowest possible errors. This emphasizes the potential of GLONASS for use with GPS in tandem for low-cost and stand-alone applications and also points towards the benefits of Multi-GNSS.

GLONASS and satellite geometry

Relative position of the used satellites and satellite geometry play a vital role in accuracy of navigation solutions. A quantitative measure of satellite geometry is dilution of precision (DOP) value; specifically Position Dilution of Precision (PDOP) is related to 3D position solution as shown in the following self-explanatory equation.

3D error in position 1σ = (PDOP) × user to satellite range error 1 σ (3)

Observations on offered satellite geometry in GLONASS, GPS and MIX operations are presented here. Available data in each mode using Rx #1 from different locations are collected and grouped based on PDOP range bins of variable widths. For each GNSS mode, percentage of occurrence of PDOP and cumulative occurrences are calculated for a range bin. Figure 6 shows the cumulative PDOP distribution for GLONASS operation for few months where the percentage values have been showed against higher boundary of the bin range.

Comparison of average PDOP in GPS, GLONASS and MIX operation modes obtained from different locations are presented in Figure 7. A more detailed comparison of PDOP in these modes is presented in Figures 8 and 9 that show the distribution and cumulative values of PDOP distribution respectively. Figures 7, 8, 9 and similar results for other months implies that GLONASS alone provides inferior geometry but helps in obtaining best configuration through MIX operation [7].

GLONASS signal strength

Next study presented here is on signal strengths of different systems. Location (elevation and azimuth) and signal strength information (Signal to Noise Ratio (SNR)) for satellites having visibility from horizon to a large elevation were collected and subdivided into elevation angle range

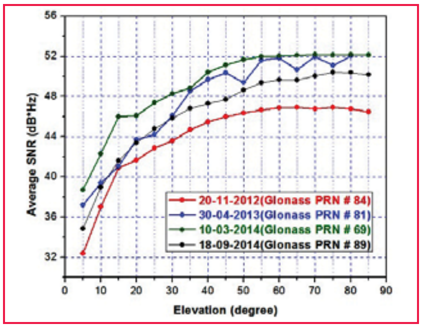


Figure 10: GLONASS signal strength variation with increasing elevation (Rx #2, LId: #1)

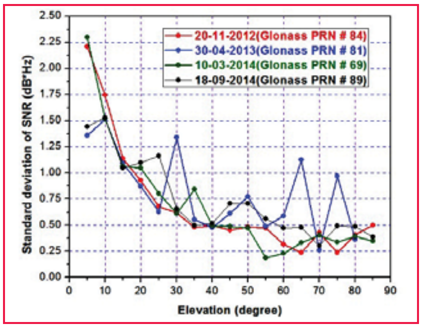


Figure 11: Standard deviation of GLONASS signal strength in 5^0 elevation bins (Rx #2, LId: #1)

bins of 5^0. Average SNR values for L1 C/A signals for GPS, GLONASS and standard deviation of SNR values for the satellites lying within the elevation angle range bins were calculated and shown graphically in Figures 10 and 11, where the values were plotted against higher elevation range bin boundaries. GLONASS L1 C/A signals show SNR values better than 40 dB*Hz for elevation angles exceeding 20^0, signal strength becomes stable with lower jitter above 30^0 elevation and saturates above 60^0-70^0 with a nominal SNR around 48 dB*Hz.

Simultaneously obtained signals from GLONASS and GPS satellites are compared and results are shown in Figures 12 and 13. Inspection of results points towards increasing SNR values with elevation and saturation beyond 60^0 elevation angle. Interestingly, GLONASS seems to provide stronger signal strengths over GPS [8]. This result may be useful from receiver design purposes in TTFF considerations.

Conclusions

The results presented here are based on long-term study using data collected

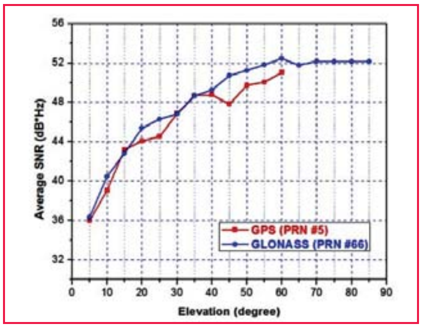


Figure 12: Comparison of average GNSS signal strength variation (Date: 19 September, 2014, Rx #2, LId: #1)

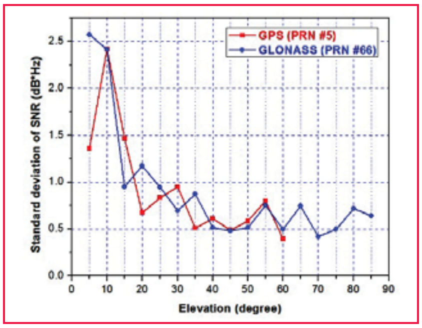


Figure 13: Standard deviation of GNSS signal strength variation within 5^0 elevation bins (Date: 19 September, 2014, Rx #2, LId: #1)

from scattered locations in India, and therefore is expected to be valid for the wide Indian sub-continent region. GLONASS, as the only current global alternative to GPS, is capable of providing system independence and redundancy to the users in stand-alone mode. With growing interest on Multi-GNSS, efficient use of GLONASS may play an important role in defining the GNSS business road map in the Indian region.

The presented results, using revitalized GLONASS, show sufficient visibility with good signal strengths and excellent satellite geometry for MIX operations. Accuracy provided by GLONASS alone is slightly inferior to GPS but supports MIX operation. It may be concluded that stand-alone, low-cost and single frequency GLONASS operation would be useful for the users of the Indian region, while more effort is needed for GPS-GLONASS interoperability and unexpected system failure issues [9].

With upcoming new global and regional navigation systems, in future, it would be of interest to study their performances and advantages in individual and in integrated modes of operations from India.

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China's land registration: Challenges and efforts

Land registration information management and inquiry system is proposed to facilitate the standardization of land registration, land registration information sharing and applications

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Overview of China's land registration

History of China's land registration

China's land registration has a very long history. According to archaeological discoveries, at least in Western Zhou Dynasty (9th century BC when China's earliest written records were confirmed), there are some records about a king granting land, including the information of the land owner and neighboring land owner (Fan 2003).

China's land registration system changed over time. The current land registration system was formed mainly since late 1980s. 'Land Management Law' promulgated in 1986 states: "Farmer collective owned land should be registered by the county government and be issued certificates to confirm the ownership. Rights of state-owned land should be registered by local people's governments above the county level and certificates should be issued to confirm the use of these rights." 'Land Management Law Implementation Regulations' states: "State implement land registration system according to law." In 1989, the Bureau of Land Management (MLR predecessor) introduced 'Land Registration Rules', stipulating land registration procedures and requirements. After 'Property Law' was enacted in 2007, MLR amended 'Land Registration Rules' and promulgated 'Land Registration Measures' that constitutes the legal basis and institutional framework of China's current land registration.

> Since 2010, as one important measure of the national strategy for rural development, rural land ownership registration has been the focus of the government, especially for local government and their land administration departments

Progress of China's land registration

In urban areas, especially in cities, the local governments (primarily counties, municipal government and land administration department) have been carrying out land registration since the late 1980s, and most cities have almost completed the registration of built land within the cities.

Though China has also started to carry out land registration in rural areas since the late 1980s, the rural land registration has a relative smaller coverage compared to urban land registration, while some registrations are not up to date and some other information are missing. So in 2010, as a measure to support the economic and social development in rural areas, the State Council launched the national land registration campaign for the ownership of farmer collective owned land in such regions. By the end of 2012, the registration of rural land ownership had almost finished and the registration rate had reached 94.7 percent (MLR, 2012). For the use rights registration of farmer collective owned land in rural areas, though the registration rate is about 80% according to statistics data (MLR, 2011), there are some problems such as outdated information, low measurement accuracy and even lack of cadaster map; so the work must emphasize in the following years to promote the land registration of use rights of farmer collective owned land in rural areas.

Current land registration system in China

Currently, China's land registration system is primarily stipulated by 'Property Law' and 'Land Registration Measures'.

Types of land registration

According to 'Land Registration Measures', the types of land registration include total land registration, initial registration, change of registration, cancellation of registration and other registration. Total land registration means making an effort to register land as much as possible within a certain time in a specific area. Initial land registration refers to the first registration of one parcel of land, except the cases in total land registration. Change of registration refers to the situation when some information is changed, such as transfer of land, or changes of owner's name. Cancellation of registration is carried out when the land rights have ended. Other registration refers to those other than the above mentioned ones, including correction of registration, registration of objection, registration of notice, and registration of warrant of seizure.

The general procedure of land registration

The basic procedure of land registration is divided into four steps: Application for land registration, land tenure censorship, registration, and issuance of certificates, though different types of land registration may have small differences in their procedure.

Application for land registration

'Land Registration Measures' states "land registration shall be based on the application for land registration, except situations stipulated by laws and regulations." To apply for land registration, the applicant has to submit proof of personal identity, proof of land rights, cadastral survey data and other materials in accordance with regulations. Under special circumstances, such as registration authorities confirming that the applicant has a fraud in its land registration; then the registration authorities can carry out the cancellation of registration in accordance with prescribed procedure without any application.

Land tenure censorship

After the application has been accepted, the land registration agency has the responsibility to censor the documents submitted by applicants to determine if the registration application should be admitted. Comments and advice will be given to government at or above county level. Then the local government will make the decision to register or not. There are three principle criteria for censorship: Legal right, clear boundary and accurate area. Only a staff member with a license can conduct land tenure censorship in land registration.

Registration

After land registration is approved, the registration will be conducted to record the information. Upon registration, land rights take legal effects. Land registration agency and the person responsible shall take the onus for the mistake. In recent years, there have been some cases that the land registration staff was prosecuted against breach of duty for their mistakes in land registration.

Issuance of certificate

After the land was registered, the land administrative department that acts as land registration agency will issue a land certificate to the applicant in accordance with the registration result on behalf of the government. Currently, there are four types of land rights certificates: "Certificate for use right of state-owned land," "certificate for ownership of farmers collective owned land," " certificate for use right of farmers collective owned land," and "certificate for other land rights."

Features of China's land registration system

Legal Effect of land registration

'Property Law' states "the establishment, change, transfer and elimination of real property take effect after registration; without registration, no effectiveness, except the situations stipulated by laws. Ownership of natural resources belong to the state and don't need to be registered."

Principal of application

Land registration can only be conducted on the basis of the application on applicant's own accord, except in situations stipulated by laws and regulations. It is not compulsory to apply for registration.

Territory registration

The applicant should submit the land registration application to local land administrative department of governments at or above county level. And theoretically, local government will register land rights and issue right certificate, but in reality, land administrative department of government carries out the tasks of land registration on behalf of the local government.

Land register is the legal basis for land rights

Land register has the highest legal authoritative. Information documented in land certificates shall be consistent with the land register, except when there is affirmative evidence that the land register does have errors.

Land registration information is available for query

According to "land registration information public query measures" issued by MLR in 2002, the results of land registration, including land register and cadaster survey map, are open to queries, but it cannot be implemented in reality. It is possible for some public agencies like police, court and revenue department to provide the registration information.

Land registration agents

China has set up a system of land registration agents who can help applicants apply for registration. In some places, there already are some established land registration agents and companies, and some provinces have established provincial association of land registration agents. Currently, the state association of land registration agents is in the phase of preparation.

Buildings are not included in land registration

Land registration is limited to a narrow scope that means only land, not including housing and other buildings on the land, as well as attachments, are registered in land registration.

Challenges of China's land registration

Dispersed land registration

In accordance with the dispersed land administrative system, land was registered by several departments (He, 2013) and has different land registers and procedures. For ownership of farmers' collectively owned land, rights are used for construction, for villager's housing, land mortgage, easements, etc. These can be registered by the land administrative department. For rural land contracted management rights, prairie ownership, rights of water and coastal mud flat for breeding aquatics were registered by the agriculture administrative department; ownership and use rights of forestry and woodlands were registered by the forestry administrative department; and housing ownership were registered by the housing and construction administrative department.

Dispersed land registration brings a lot of problems. For land is registered by different departments according to different criteria. Without sharing of information, conflict or inconsistency will inevitably occur. For instance, one parcel of land registered by forestry administrative department may overlap with other parcels of land registered by agriculture administrative department. Land registration was scattered in different administrative departments and not sharing of registration information is not conducive to protect land rights and to secure land transactions. Also, overlapping of registration administrative institutions increased fiscal spending and reduced administrative efficiency.

Relatively lagging land registration in rural areas

In urban areas, almost all land has been registered, though some still 'haven't been digitally recorded. While in vast rural areas, some lands are not registered yet, and even among the registered ones, most have the widespread problem of incomplete and outdated information. There are some cases that right holder has the land certificate while the registration agency doesn't have any documents and information about the land registration. Also, there are some cases in which what has been recorded in the registers is inconsistent with the reality for there is no constant update. We also can find some mistakes in rural land registration.

The reasons of relatively lagging rural land registration could be the poorer working conditions of land registration in the 1980s and 1990s, and less attention was paid to land registration at that time because rural lands were strictly restricted in terms of rights.

Efforts made to improve China's land registration

Implementation of unified land registration system

In December 2013, the State Council clearly stipulated that Ministry of Land and Resources should be responsible for the guidance and supervision of real estate registration, including houses, grasslands, woodlands, waters, etc. The unified system could be demonstrated in 'four unity', which are unity of registration agency, unity of register, unity of registration regulation and unity of registration information platform

Though 'Property Law' enacted in 2007 has already proposed "national unified registration system for real estate," there is very few progress on the way of implementation. Until early 2013, in the "institutional reform of the State Council and the functional transformation plan," the State Council pledged to "reduce overlapping responsibilities of departments to maximize integration of the same or similar functions which were dispersed in different departments of the State Council. The duties of housing registration, woodlands registration, prairie registration and land registration should be integrated in one department." In December 2013, the State Council clearly stipulated that Ministry of Land and Resources should be responsible for the guidance and supervision of real estate registration, including houses, grasslands, woodlands, waters, etc. The unified system could be demonstrated in 'four unity', which are unity of registration agency, unity of register, unity of registration regulation and unity of registration information platform. Therefore, currently unified land registration system is in the early stage of implementation.

Unified land registration, which will be carried out by land administrative department, will need close cooperation of various administrative departments and a step by step transition is anticipated. The first task is to build the working mechanism for the close cooperation of various departments. Land registration has a very close relationship with land administration, so in accordance with the still dispersed land administration system, unified land registration needs close cooperation within various departments, especially in sharing of information.

The second task is to gradually collate and integrate original land registration information recorded by various departments, and at the same time, it is very important to make sure that all certificates that have been issued should remain valid. The third task is to gradually integrate registration agency. At the level of central government, the Cadaster Department in the Ministry of Land and Resources will have another institution such as the Bureau of Real Estate Registration to guide and supervise the unified land registration. At the level of local government, it is also needed to integrate the registration agency, particularly at the level of county or municipal government for they are the concrete agencies to register in accordance to the principle of territoriality registration.

Efforts for rural land registration

Since 2010, as one important measure of the national strategy for rural development, rural land ownership registration has been the focus of the government, especially for local government and their land administration departments. The registration of farmers collective owned lands have been basically completed by the end of 2012, and the government has shifted their focus to the land use rights registration in rural areas, mainly including rights of land for construction and rights for villager's housing.

Currently, a lot of local governments are boosting rural land registration. They try to register what hasn't been registered earlier and to supplement or update what has been registered before. In the new round of rural land registration, new survey methods are widely used to improve the measurement accuracy. Another main task of new round of rural land registration is to promote the land registration information system construction. Land registration information management and inquiry system is proposed to facilitate the standardization of land registration, land registration information sharing and applications.

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Determination of geoid in Saudi Arabia using global gravity model and GPS/benchmark data

The results may indicate that refinement of undulation of Global Gravity Field Model with GPS/Benchmark data have given the preliminary values of geoid undulations acceptable for practice purposes for the Kingdom

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Existing national geodetic vertical network of Saudi Arabia

The current National Geodetic Vertical Network (NGVN) in the Saudi Arabia is based mainly upon a series of leveling runs carried out during 1966 - 1970. About 54 levelling circuits were carried out over a distance of 1,952 km of first order leveling and 13,002 km of second order levelling and around 2,500 benchmark established at an average of 6 km. These benchmarks are generally along the major routes and 50-100 m off the road.

The accuracy was specified as first, second and third order leveling criteria of classification of leveling network. Around 809 benchmarks of the 2,500 ground markers were spirit levelled. The rest were heighted by reciprocal vertical angles.

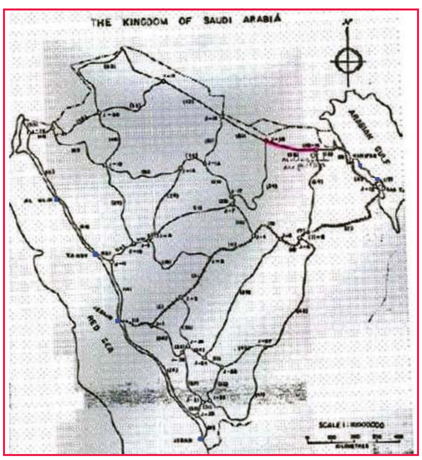

Figure 1: National Geodetic Vertical Network of Saudi Arabia

The vertical datum based on six recording tidal observatories have data from April 1969 to March 1970. These observatories are located in Jeddah, Yanbu, Al-Wajh, Gizan, Manifah and Ras Tanurah, as shown with a blue colored square in Figure 1. (Nakiboglu, S.M.et all, (1994).

Concrete monuments were installed in all non-rocky and non-sandy locations. In rocky locations where excavation proved difficult, a shortened central tube was used. In sandy locations liable to erosion, the three m pipe marker was installed with witness posts.

A comprehensive field reconnaissance has been carried out based on the existing benchmarks. Height data was collected, classified and evaluated for GPS surveys. Many of the benchmarks of NGVN have subsequently been destroyed and/or lost during development work, and that only as few as 20% has been recovered in some areas (see Figure 2).

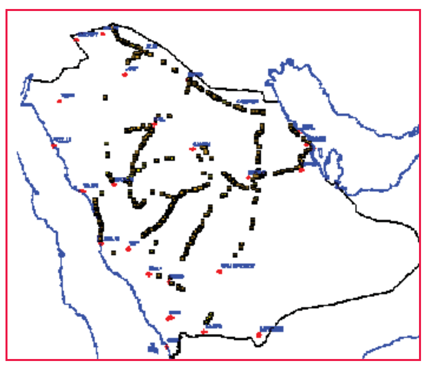

Figure 2: Recovered banchmark geometry with horizontal coordinates of NGVN

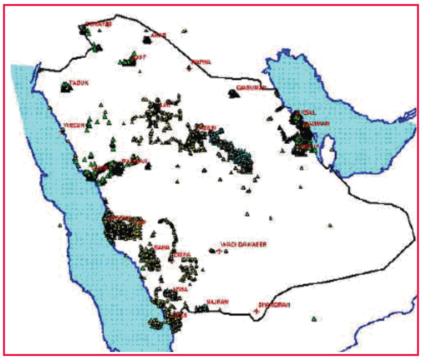

Figure 3: Additional banchmark geometry with horizontal coordinates

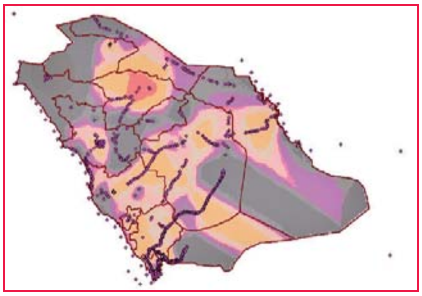

Figure 4: All points used to test gridding algoritms

Additional benchmarks established through out the projects by municipalities and other agencies have been included in the process. (See Figure 3)

By examining the existing benchmarks, it was decided that spirit leveling would be carried out in mostly those areas where existing benchmarks were inadequate and the geoid, steep. In this context, we selected South-West and South of Saudi Arabia for spirit leveling. The total distance of monumented lines of spirit leveling works was around 2,000 km, where benchmarks were constructed at 5 km intervals and named in a way to be consistent with the existing leveling network. As a result, the total number of benchmarks used to refine The Earth Geo-potential Model EGM96 is about 3,800 points. (see Figure 4)

Vertical control analysis showed that the existing leveling network was adjusted to a mean sea level value derived from the tidal observation at Jeddah, Yanbu, Al Wajh, Jizan, Manifah and Ras Tanurah. But, unfortunately, the uncertainties of benchmarks elevations are not available. The only estimation regarding the reliability of benchmarks may be deduced from the difference in elevation obtained from opposite runs that shall not be greater than first and second order leveling criteria of classification of leveling network. Therefore, this concept has been followed during the work.

Relations between orthometric heights and geoid

The GPS measured heights are measured from the ellipsoid; therefore, they need to be converted into an orthometric height system. The current methods of converting GPS elevations to orthometric elevations (Martin, Daniel J. (2001)) are:

- To incorporate a priori geoid undulation data in three-dimensional (3D) adjustment, which holding the benchmark elevations fixed for stations with known values, have to be determined by spirit leveling. The minimum number of benchmarks should be four and well distributed throughout the region.
- Determination of orthometric heights from GPS vector baseline data involves performing 3D adjustment without using geoid undulation data. In this method, the benchmarks elevations are held fixed while using zero values for geoid undulations in a 3D adjustment. This interpolates the geoid undulation values for the remaining stations in the region. Here also, a minimum of four known benchmarks are needed and preferably more than four well distributed benchmarks to achieve valid results.
- The best method is to compute the actual geoid undulation difference details from gravitational anomalies for the desired stations, wherever centimeter accuracies are derived.

The ultimate aim for the vertical network is to determine a geoid surface across the region, in such a way that GPS observations can be corrected so that they agree with the orthometric height datum.

An initial assessment of problems associated with the geoid was made using the observed WGS-84 coordinates with GPS points across the region. From the differences between GPS and orthometric height, the initial values for the geoid separation, N_{MSL} (see Figure 5) was determined.

This figure was then compared with the value given by the N_{EGM96} global Earth model. The statistical results are shown in Table 1.

RMS of residuals variations is 0.749 m. However, considering the known accuracy of EGM96, the type of terrain and the area covered, these variations are far greater than would be expected.

Global gravity field model, EGM96

The global Earth Gravity Model for 1996 (EGM96) is the result of a collaboration

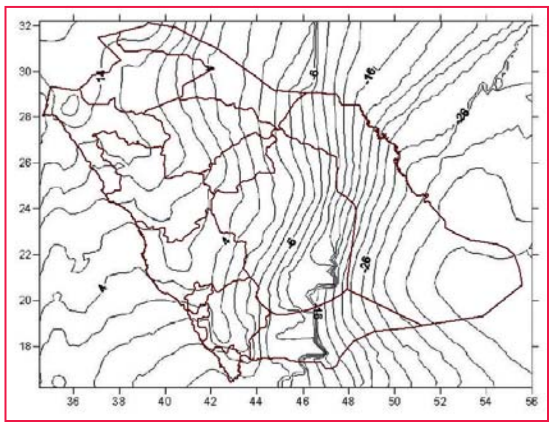

Figure 5: WGS84 geoid of The Kingdom

Table 1: Statistical result of base points of comparison between WGS84 and EGM96 geoids

	Observed geoid minus EGM96 residual variations for base points
Min [m]	-3.376
Max [m]	2.490
Average [m]	0.148
RMS [m]	0.749

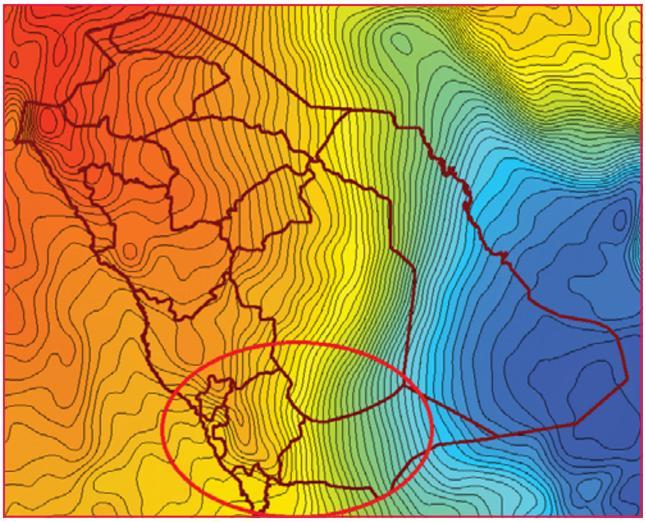

Figure 6: EGM96 Geoid Model for the Saudi Arabia

between the National Imagery and Mapping Agency, NASA Goddard Space Flight Centre, and the Ohio State University. The collaboration was for covering the Earth gravity field up to degree and order 360. This corresponds to a spatial resolution of up to 55 km and models the geoid within an accuracy of about 40 cm (global average).

For a further refinement of the EGM96 in the Saudi Arabia, surface point information has to be introduced. A point separation of less than 30 km is needed to cover the short wave length part of the harmonic development of the Earth gravity field (degree 361 . . . 10000, 0.5 m . . . 0.01 m geoid undulation, point separation 30 km . . . 1 km (grid wise)).

Figure 6 shows the part of the EGM96 model that covers the Saudi Arabia. Proceeding along the 19-degree latitude, circle from west to east (from Baha to Sharurah, marked with the circle in red), a steep increase of the geoidal height of about 5 m (from 3 m to -2 m) occurs over a short distance of less than 100 km.

Determination of geoid throughout the KIngdom

In order to determine the geoid throughout the Kingdom, recovered benchmarks (BM) from existing vertical network, selected constraining points on water surfaces around The Kingdom and newly-established benchmarks (GPS-BM) where the geoid steep and benchmark established through projects by different agencies, have been used. The orthometric heights of all the points on ground are known from leveling activities. With ellipsoidal heights coming from global navigation satellite system (GNSS), we have the geoid heights for all these points from the famous relation (1).

Furthermore, the points on water surfaces have known orthometric heights of zero. Since these points are used exclusively for constraining purposes, it is thought to be sufficient to take their geoid heights from EGM96. This gives us enough data to estimate the ellipsoidal height at these points, if needed.

Both sides of Equation (1) may be arrived at by separate means. EGM96 model can give one estimate of geoid height (N_{EGM96}) and removing the orthometric height from an ellipsoidal height (N_{MSL}, geoid as derived from actual survey data) will yield another. The residual difference between these two estimates and N_{MSL} was processed to develop a model of the correlated signal according to:

$$h_{GPS} - H_{BM} = N_{GPSBM} = N_{MSL} \quad (1)$$

$$h_{GPS} - H_{BM} - N_{EGM96\text{–}EGM} = \Delta N_{MSL\text{-}EGM} \quad (2)$$

where: *H:* is the orthometric height; *h:* is the ellipsoidal height; *N:* is the geoid height.

This process involved determining a conversion surface that approximated the correlated signal existing in GNSS-BM residuals ($\Delta N_{EGM\text{-}MSL}$) and N_{MSL}. In this context we tested the following algorithms with the powerful software packages 'Golden Surfer 8' and home-made software for the determination of the analytical geoid and residual geoid surface (Golden Software, Inc, Briggs, I. C. (1974), Nakagawa, H. et al (2003), Ghilani, Charles D. et all. (2002), Journel, A. G. et all. (1978), Kitanidis, P. K. (1997), Martensson, S. (2002)).

- Bi-Cubic Spline;
- Inverse Distance to a Power;
- Kriging;
- Least Squares Collocation;
- Modified Shepard's;
- Moving Average;
- Polynomial Regression;
- Trigonometric Function; and
- Thin-Plate Smoothing Spline based on Collocation Matrix

Initial tests revealed better results of two algorithms when compared to others, for GNSS-BM residuals ($\Delta N_{EGM\text{-}MSL}$) and N_{MSL}. These were: Kriging and Thin-Plate. Thus, we continue herein with these algorithms only.

Each algorithm was used to fit a surface to the available points in hand. Then that surface was used to interpolate for the heights at the same points (base points) and at the points that are not used to fit a surface (rover points) we have on land. This interpolation was done using Biharmonic Spline algorithm (Sandwell, D. T. (1987).

Since we already know the heights of these points, and since we are using unified interpolation algorithm, we could then judge which of the two gridding techniques give better results for our specific test case.

All this was done twice - once with the geoid (N_{MSL}) heights of the points themselves, and once with the differences between these heights and those acquired from the global Earth Gravity Model for the year 1996 (EGM96_N), as shown in Figure 6 for Saudi Arabia. The second methodology allows us to get rid of the trend and benefit of the precision of EGM96.

Thin Plate Surface Fitting using Least Squares Collocation Matrix Algorithm

This mathematical algorithm can be efficiently applied to geostatistical problems, where a thin-plate smoothing spline (f) is implemented such that it is the unique minimizer of the weighted sum:

P*E(f) + (1-P)*R(f) (3)

with E(f) the error measure

E(f) = sum_j { | Y(:,j) - f(X(:,j)) |^2 : j=1,...,n } (4)

and R(f) the roughness measure
R(f) = integral (D_1 D_1 f)^2 + 2(D_1 D_2 f)^2 + (D_2 D_2 f)^2 (5)

Here, the integral is taken over the entire 2-space, and (D_i) denotes differentiation with respect to the (i-th) argument. Hence, the integral involves the second derivatives of (f). The smoothing parameter (P) is chosen (ad hoc fashion) according to dependence on the sites X.

In other words, thin-plate spline approximations (f) can be created such that they satisfy, approximately or exactly, the equation for given data values (z) for z = f(x,y), at given scattered data sites (x, y) in the plane. The associated collocation matrix is provided implicitly. The spline created is in st form, as are its first-order derivatives.

Table 2: The statistics of surfaces are determined by geoid (N_{MSL}) and residual geoid ($\Delta N_{MSL-EGM}$) fitting using thin plate algorithm.

	Thin-Plate with Geoid (N_{MSL}) and Residual Geoid ($\Delta N_{MSL-EGM}$)			
	Geoid (N_{MSL})		Residual Geoid ($\Delta N_{MSL-EGM}$)	
	Base points	Rover points	Base points	Rover points
Min [m]	-1.767	-0.811	-0.886	-0.780
Max [m]	1.351	0.831	1.204	0.929
Average [m]	0.000	-0.053	-0.001	-0.034
RMS [m]	0.142	0.264	0.120	0.266

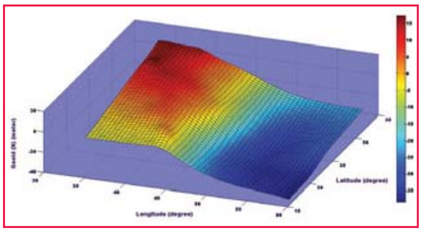

Figure 7: Fitted surface to geoid (N_{MSL}) base points values using Thin-Plate

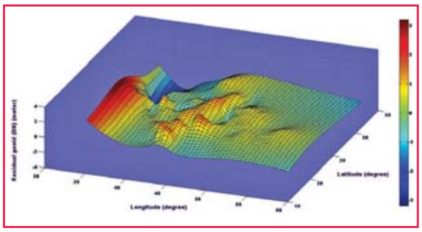

Figure 8: Fitted surface to residual geoid ($\Delta N_{MSL-EGM}$) base points values using Thin-Plate

Table 3: The statistics of surfaces determined by geoid (N_{MSL}) and residual geoid ($\Delta N_{MSL-EGM}$) fitting using kriging algorithm

	Kriging with Geoid (N_{MSL}) and Residual Geoid ($\Delta N_{MSL-EGM}$)			
	Geoid (N_{MSL})		**Residual Geoid ($\Delta N_{MSL-EGM}$)**	
	Base points	**Rover points**	**Base points**	**Rover points**
Min [m]	-1.063	-2.582	-0.648	-0.905
Max [m]	3.079	0.994	0.848	0.744
Average [m]	-0.002	-0.078	0.000	-0.040
RMS [m]	0.116	0.365	0.088	0.240

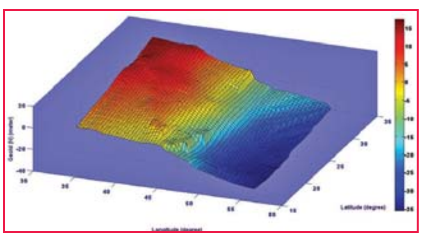

Figure 9: Fitted surface to geoid (N_{MSL}) base points values using Kriging

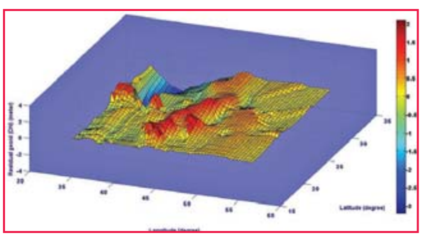

Figure 10: Fitted surface to residual geoid ($\Delta N_{MSL-EGM}$) base points values using Kriging

Within the calculations, thin-plate smoothing spline builds and uses collocation matrix for scattered data, implicitly. This makes this algorithm powerful (Golden Software, Inc).

Thin Plate algorithm was used to fit a surface to the geoid (N_{MSL}) and residual geoid ($\Delta N_{MSL-EGM}$) in hand separately. Then those surfaces were used to interpolate for the geoid heights (N_{INTP}), residual geoid heights (ΔN_{INTP}) at the same base points and at the rover points, we had on land.

The RMS of differences between geoid height and interpolated geoid height of base and rover points, residual geoid height and interpolated residual geoid height of base and rover points, has been found 0.142 m, 0.264 m, 0.120 m, and 0.266 m respectively; see Table 2. The fitted surfaces are shown in Figures 7 and 8.

This geometrical elevation grid is used in computing the residuals of the geoid heights computed from the EGM96, and adding appropriate corrections to the geoid heights of EGM96, according to the relationship shown in (2).

Surface Fitting based on Kriging Algorithm

This geostatistical algorithm has been used worldwide in various similar cases. Kriging is a technique that provides the Best Linear Unbiased Estimator of the unknown fields. It is a local estimator that can provide the interpolation and extrapolation of the originally sparsely sampled data that are assumed to be reasonably characterized by the Intrinsic Statistical Model (ISM). An ISM does not require the quantity of interest to be stationary, i.e., its mean and standard deviation are independent of position, but rather its covariance function depends on the separation of two data points only (Golden Software, Inc), Kitanidis, P. K. (1997), i.e.

$$E[(z(x) - m)(z(x') - m)] = C(h) \quad (6)$$

where m is the mean of z(x) and $C(h)$ is the covariance function with lag h, with h being the distance between two samples x and x':

$$h = \| x - x' \| = \sqrt{(x_1 - x_1')^2 + (x_2 - x_2')^2 + (x_3 - x_3')^2} \quad (7)$$

While the RMS of differences between geoid height and interpolated geoid height of base and rover points, residual geoid height and interpolated residual geoid height of base and rover points, has been found 0.116 m, 0.365 m, 0.088 m, and 0.240 m respectively see Table 3. The fitted surfaces are shown in Figures 9 and 10.

Results and discussions

All these analytical surfaces can be considered to compute the residual geoid heights with respect to the EGM96 surface throughout Saudi Arabia. Then, these corrections can be added to the corresponding EGM96 geoid heights to obtain improved geoid heights at these points.

In order to estimate the accuracy, comparisons have been made for both cases of geoid and residual geoid using two algorithms mentioned above. The statistical results are seen in Table 2, Table 3 and Table 4 for geoid and residual geoid fitting for both algorithms respectively.

It is reasonable to interpret the results as geoid precision. These discrepancies are due to error sources from GPS and leveling surveys, mathematical model used as well as from the EGM96 itself.

The results in Table 3 indicate that Kriging has yielded the best fitting analytical surface for residual geoid fitting. Therefore, this algorithm was used for the computation of conversion surface of Saudi Arabia.

The geoid conversion surface is estimated to yield decimeter level precision geoid height throughout the Kingdom. Of course, the precision varies depending on the proximity to GPS leveled benchmarks. It is higher in the vicinity of such points and gets lower as the distance gets higher.

It is to be pointed out that the geoid conversion surface of Saudi Arabia input data is not error free. It can be concluded that both ellipsoidal heights determined by GPS techniques and orthometric heights determined by geometric leveling have precision in centimeter level.

The RMS of differences between residual geoid height and interpolated residual geoid height of base points and the RMS of differences of two algorithms have been found 0.088 m and 0.075 m respectively. This result may indicate that refinement of spherical harmonic geopotential model for the year 1996 with GPS/ benchmark data gave preliminary values of geoid undulations that are acceptable for practice purposes.

On the other hand, much of the current vertical control was lost due to the destruction or disruption. Because the network was not dense enough to support the use of GPS to get elevations, a precise geoid model should be determined based on a combination of gravity with GPS/ leveling.

Table 4: The statistics of differences surfaces determined by geoid (N_{MSL}) and residual geoid fitting ($\Delta N_{MSL-EGM}$) using both thin plate and kriging algorithms

	Differences of Thin-Plate and Kriging			
	Geoid (N_{MSL})		Residual Geoid ($\Delta N_{MSL-EGM}$)	
	Base points	Rover points	Base points	Rover points
Min [m]	-1.101	-2.125	-0.945	-0.470
Max [m]	2.967	0.786	0.652	0.414
Average [m]	-0.003	-0.025	0.001	-0.006
RMS [m]	0.118	0.265	0.075	0.106

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ANS directorate of AAI conferred 'Golden Peacock Award

Air Navigation Services (ANS) directorate of Airports Authority of India (AAI), has been awarded the prestigious 'Golden Peacock Award for Innovative Product/Service for the year 2015' by the Institute of Directors, the international body of company directors. Mr V Somasundaram, Board Member (ANS), AAI received the Award at the Award ceremony held at Dubai on 20th April 2015 from His Highness Sheikh Nahyan bin Mubarak Al Nahyan, Minister of Culture, Youth and Social Development, Government of U.A.E. The award was conferred based on an assessment, by an independent jury, of the over-arching goal to continue modernizing the ANS infrastructure to meet the customer needs and manage and operate the Air Navigation Services in a safe, efficient and cost-effective manner.

Japan's QZSS GNSS to benefit Australia

A team of Australian and Japanese researchers have tested a new satellite positioning system that will improve upon the US' GPS system by additionally transmitting augmentation signals to improve positioning performance, ultimately boosting the productivity of Australia's rural industries and benefitting the working and personal lives of many, particularly those living in regional and outback areas.

The system is known as the Japanese Quasi-Zenith Satellite System (QZSS). The first QZSS satellite is already in orbit. When fully deployed in 2023, the constellation will consist of seven satellites providing 24 hours coverage to the region.

The orbit configuration of these satellites will give continuous coverage at high elevation angles, providing improved satellite navigation in areas that challenge traditional GNSS satellite positioning capabilities, such as central city districts and other obstructed environments.

While intended primarily for users in Japan, the orbit design offers significant advantages to neighbouring East Asia countries, including Australia.

One of the additional augmentation signals – the L-band experimental (LEX) signal – is designed to allow high accuracy positioning in real-time through transmission of corrections for Precise Point Positioning (PPP). This additional data delivery is a critical factor in ensuring the system can provide a continuous centimetre-level positioning service. *http://www.spatialsource.com.au*

17th Beidou navigation satellite functions in orbit

A new-generation satellite for China's global navigation and positioning network has entered its designed work orbit, the satellite's developer said. Navigation equipment on the satellite was functioning and its navigation signals were being received on Earth, according to a statement by the Shanghai Engineering Center for Microsatellites (SECM). Launched on March 30, the satellite is the 17th added to China's Beidou navigation satellite system (BDS). According to Xiangli Bin, the SECM director and chief commander for the new-generation BDS satellite program, the latest satellite will have a longer life and be more accurate than its predecessors.

The first BDS satellites was launched by China in 2000. In December 2012, the system began providing positioning, navigation, timing and short message services to users in China and parts of the Asia-Pacific region. *http://news.xinhuanet.com*

GLONASS stations in China, Cuba, Nicaragua, Vietnam

Russia is negotiating possible placement of land-based infrastructure for its GLONASS system with China, Cuba, Nicaragua and Vietnam, deputy head of the Federal Space Agency (Roscosmos) Mikhail Khailov said.

"We have already established four land-based GLONASS signal adjustment stations abroad - one in Brazil and three at year-round wintering stations in the Antarctic," he said. "We are in talks with four countries, namely China, Cuba, Nicaragua and Vietnam." In his words, about 20 such facilities abroad are needed to better accuracy. Twenty more such facilities are located in Russia.

Khailov said the technological period for placing and commissioning GLONASS infrastructure facilities outside Russia was two to three years. "However this is the subject for negotiations and the issue of actual terms is open until the negotiations are over," he said. *http://in.rbth.com*

Beidou to expand coverage globally by 2020

The Beidou satellite navigation system will be fully operational worldwide by 2020, said Li Jian, deputy director of the Civil Aviation Administration of China (CAAC).

The system has been successfully tested in the general aviation sector, which includes all civil aviation operations other than scheduled air services, as well as by general aircraft including helicopters and private jets. *http://www.wantchinatimes.com*

New GLONASS stations to appear in Antarctica

New measuring stations for the GLONASS space-based satellite navigation system will be deployed in Antarctica until 2020. Scientists expect it will enable the control of more than 90 percent of satellite orbits and believe it could bring parity between Glonass and GPS.

Scientists from the Krasnoyarsk Territory and St. Petersburg plan to deploy an additional four to seven stations for the GLONASS in Antarctica by 2020 in addition to the three already operating on the continent. This will greatly improve the accuracy of the country's navigation system.

This is not being done to enhance the consumer potential of GLONASS, stressed Yury Fateyev, a professor at Siberian Federal University. "These stations are used to set up functional additions to the GLONASS system for special applications – mainly for geodesy," Fateyev said referring to the science of measuring and monitoring the Earth's shape and size. "What we are now


PENTAX
Scanning System S-3180V
3D laser measurement system
3D
S-3180V
TI Asahi
+ Integrated HDR camera allows combination of brilliant colours with high-resolution scan data
+ The fastest laser-scanner over 1 million points/second
+ Eyesafe laser class 1
+ IP53 dust & water resistance

Galileo update

Seventh and eighth satellites join the Galileo constellation

Two new Galileo satellites have been successfully placed in orbit, joining the existing six probes in the constellation. The operation went off without a hitch – something that can't be said for the troubled assent of the fifth and sixth Galileo satellites.

The two new satellites were launched into orbit on March 27 from Europe's spaceport in French Guinana. All stages of the Soyuz rocket assent vehicle were performed as planned, with the probes being released at their target altitude of 23,500 km (14,600 miles), some 3 hours and 48 minutes after liftoff. *ESA*

EU to launch 4 more Galileo satellites in 2015

Four more Galileo satellites will be launched this year following the successful launch of two satellites recently. The next launch of Galileo satellites was scheduled for September 2015, the European Commission (EC) stated, according to a Xinhua report. *http://gadgets.ndtv.com*

Galileo NAGU announces completion of ground upgrade

The European GNSS Service Centre has issued Notice Advisories to Galileo Users announcing the completion of a ground segment upgrade and system testing as of 1 April 2015. The three fully operational Galileo satellites (GSAT0101, GSAT0102, and GSAT0103) have been declared available from 1 April 2015 at 00:00 UTC.

- GSAT0101 (ID:11) payload on PHM clock
- GSAT0102 (ID:12) payload on RAFS clock
- GSAT0103 (ID:19) payload on PHM clock
- GSAT0104 (ID:20) is still considered unavailable as it only transmits an E1 signal.
- GSAT0201 (ID:18) and GSAT0202 (ID:14), although now in improved orbits, have not been declared available.

Meanwhile, the two recently launched satellites (GSAT0203 and GSAT0204) are slowly drifting to their assigned orbits. They are not yet transmitting standard L-band signals.

Honeywell technology approved for use on ESA Galileo program

Honeywell announced that its Global Tracking solution has passed the final acceptance test for use on Galileo search and rescue program. Honeywell Global Tracking, part of Honeywell's scanning and mobility business, is working in partnership with the aerospace and defense division of Capgemini, the prime contractor for the Galileo search and rescue program, to deliver a high-precision positioning system that is fully compatible with the international Cospas-Sarsat standard. *http://www.satellitetoday.com*

Fifth Galileo Colloquium Planned for October

The fifth International Colloquium on Scientific and Fundamental Aspects of the Galileo Programme will be held in Braunschweig, Germany, Oct. 27–29. Since 2007, the worldwide scientific community has met every two years to discuss the scientific possibilities of Galileo and other GNSS.

deploying in Antarctica are measuring stations for the GLONASS system itself. They take measurements to determine the parameters of satellite orbits."

Navigine signs deal with GLONASS on indoor navigation

Leading Skolkovo IT resident Navigine is to glean its geolocation data for its indoor navigation technology from Russian provider GLONASS in a deal signed this week between the two parties. The agreement commits Navigine and GLONASS to jointly develop the Russian market for indoor navigation services.

Navigine is a platform for high-precision indoor location services using existing sensors inside smartphones and Wi-Fi or Bluetooth connectivity. The technology can be used anywhere from airports to shopping malls; from warehouses to hospitals, and helps with navigation, marketing, analytics, consumer behavior, and staff and vehicle tracking. *https://sk.ru*

Navigation cooperation between Pakistan and China

Pakistan and China has agreed to a number of partnership and cooperation initiatives, including effort to strengthen their cooperation on remote sensing and navigation technologies. The cooperation extends to applications for these technologies in communications, hydrology, geology, disaster management, port management, mineral prospection, food security, water prospection and other areas for seeking potential advantage in social and economic development. *www.asmmag.com*

The Ninth GPS-IIF Satellite Has Been Set to Healthy and Usable

The ninth GPS-IIF satellite, SVN-71/PRN-26, launched on 25 March 2015, has completed its operational checkout and was set to healthy and usable Monday, 20 April, 2015. See NANU 2015028 below. This brings the number of satellites transmitting the L2C signal to 16 and those transmitting the L5 signal to 09. The next GPS-IIF satellite, IIF-10/SVN-72 is tentatively scheduled for launch 16 June 2015.

FARO PointSense for Autodesk Revit software

FARO Technologies has released newly designed PointSense for Autodesk's Revit® building design software. It introduces functionality to improve the evaluation and conversion of point cloud data to Building Information Modeling (BIM). The latest software release accelerates and simplifies the analysis and design of laser scan data directly in Autodesk Revit®. *www.faro.com/india*

3D mapping of New Delhi in preparation for smart city planning

The New Delhi Municipal Council has approved a project to start 3-D mapping as a precursor to planning for their smart city initiative. The work will include the mapping of buildings, streets, trees and water and sewer lines. The agency will hire a private firm to conduct the project.

Smart maps, an $8 bn opportunity for India!

Smart maps and dynamic mapping technologies will be critical tools for the development of India's smart cities project. It can help India gain upwards of $8 billion in savings and value, save 13,000 lives, and reduce one million metric tonnes of carbon emissions a year, in cities alone. According to a study, Smart Maps for Smart Cities: India's $8 billion+ Opportunity by Dalberg Global Development Advisors and Confederation of Indian Industry (CII), smart maps can facilitate the development of smart cities in little ways that add up to huge economic benefits for citizens, businesses, and government. *www.business-standard.com*

OGC calls for participation in major sensor IoT Interoperability Pilot Project

The Open Geospatial Consortium has issued a Request for Quotations/Call for Participation (RFQ/CFP) in the OGC Incident Management Information Sharing Internet of Things Pilot Project (IMIS IoT Pilot). Participants in the IMIS IoT Pilot will prototype and demonstrate standards-based approaches to a series of challenges that hinder effective use of large numbers of diverse sensors for use in emergency response and disaster response situations. OGC pilot projects apply and test OGC standards in real world applications using Standards Based Commercial Off-The-Shelf (SCOTS) products that implement OGC standards and other related standards. Organizations selected to participate in the IMIS IoT Pilot will develop solutions based on the sponsors' use cases, requirements and scenarios, which are described in detail in the RFQ/CFP.

Jack and Laura Dangermond, founders of Esri, felicitated

The National Audubon Society has awarded two of the nation's most prestigious environmental honors: the Audubon Medal and the Dan W. Lufkin Prize for Environmental Leadership. Jack and Laura Dangermond, founders of Esri, were awarded the prestigious Audubon Medal, recognizing them for their outstanding achievements in the field of technology and conservation innovation, and support for research institutions, schools, and non-profit organizations. *Source: National Audubon Society press release. https://medium.com/*

New Mining Cadastre System in South Sudan

The Minister of Petroleum and Mining in South Sudan recently launched South Sudan's new Mining Cadastre System. The project included the implementation of FlexiCadastre to meet the requirements of the Mining Act of 2012 and the Mining Regulations of 2015 as well as the launch of a view only map portal. The map portal is now available at portals.flexicadastre.com/southsudan/.

Adoption of National Mapping Policy in Nigeria

The Nigerian Institution of Surveyors (NIS) has urged the President-elect, General Muhammadu Buhari, to institute a government that would operate a deliberate policy of involving professional associations to promote sustainable development. Omo Akhigbe who said NIS as a mouthpiece of surveyor's in the country was expectant of a Buhari government that would promote massive investment in surveying and mapping to confront the various challenges facing the nation. *AllAfrica.com*

'Vulnerability Mapping' to help farmers in India

To keep a check on farmer suicides in several districts of Maharashtra, Chief Minister Devendra Fadnavis unveiled a project for "vulnerability mapping" of agriculturists in the worst-hit Yavatmal and Osmanabad districts. It will enable targeted intervention by 10 departments to mitigate their sufferings. *http://www.ndtv.com*

IoT platform revenues will grow to € 2.4 billion worldwide in 2020

The global market for third party Internet of Things (IoT) platforms will show solid growth in the next few years, according to Berg Insight. Total IoT platform revenues are forecasted to grow at a compound annual growth rate (CAGR) of 32.2 percent from € 450 million in 2014 to € 2.4 billion in 2020. Third party IoT platforms are relatively new in the market and display a great diversity in terms of functionality and application areas. *berginsight.com*

Researchers test smartphones for earthquake warning

Introstart smartphones and other personal electronic devices could, in regions where they are in widespread use, function as early warning systems for large earthquakes according to newly reported research introend. This technology could serve regions of the world that cannot afford higher quality, but more expensive, conventional earthquake early warning systems, or could contribute to those systems.

The study, led by scientists at the U.S. Geological Survey and published April 10 in the inaugural volume of the new AAAS journal Science Advances, found that the sensors in smartphones and similar devices could be used to build earthquake warning systems. Despite being less accurate than scientific-grade equipment, the GPS receivers in a smartphone can detect the permanent ground movement (displacement) caused by fault motion in a large earthquake.

China's Internet leaders are adding features to sell mobile ads

Mapmakers in ancient China were renowned for innovation in accuracy and scale. As the nation's Big Three Internet companies compete to attract users to their mapping software, their focus remains much the same, with a few high-tech twists.

Online marketplace Alibaba, search engine Baidu, and messaging-app maker Tencent are pouring money into free mapping apps to draw larger mobile audiences. The location data that comes with the new users is coveted by advertisers, who can push products to people in specific places. Google Maps' share of the market has slipped into the single digits since the company stopped providing search services in China five years ago, complaining of government censorship. The three Chinese companies offer mapping features that Google doesn't. *http://www.todayonline.com*

India's UrbanClap matches customers with the best local service providers

Based in Delhi, UrbanClap wants to make finding good service providers as easy as, well, clapping your hands.

With more than 1,000 service providers currently listed, including individuals and companies, UrbanClap claims to be the largest mobile-based services marketplace in India. The startup, however, aspires to be more than just a listings platform.

Co-founder Varun Khaitan says that UrbanEye's proprietary matchmaking engine sets up potential customers with the best service providers in their area, saving them from the tedium of going through hundreds of listings or having to rely on word-of-mouth referrals. *http://techcrunch.com*

Apple being wooed by Nokia for $3.2B HERE mapping acquisition

A report claims Apple is among a number of high-profile tech companies being courted by Nokia in the Finnish firm's attempt to sell off its HERE mapping service and related assets. Nokia is seeking more than 3 billion euros (roughly $3.2 billion) for HERE's mapping assets despite the cache being valued at $2.14 billion last year. Nokia's investment in HERE's technology, including those got through acquisitions like NAVTEQ, was pegged at $8.1 billion in 2008.

For Apple, the addition of HERE could play an important role in the buildout of Apple Maps, which drew criticism when it launched in iOS 6. *http://appleinsider.com*

SimActive Version 6.1

SimActive has announced Correlator3D™ version 6.1, now with point cloud generation. The new feature builds on its autocorrelation techniques using the GPU. Point clouds are generated in parallel with digital surface models (DSMs), with virtually no added processing time. simactive.com

BlackBridge takes global positional accuracy to a higher level

BlackBridge has just completed the production and implementation of the most current and consistent global control point database on the market, Global Reference 2.0. This will significantly improve the positional accuracy of RapidEye imagery.

Global Reference 2.0 improves positional accuracy of orthorectified imagery to under 10 m RMSE on a global scale, with 80% under 7 m RMSE. This level of positional accuracy applies to ortho-products for every region of the world. *blackbridge.com*

New ideas and markets emerging based on big data from space

The Copernicus Masters competition is inviting all interested participants to submit outstanding ideas, applications, and business concepts involving innovative uses of Earth observation data by 13 July 2015. Along with cash prizes, the winners will receive access to a leading

Dr G Satheesh Reddy to be conferred with fellowship of royal institute of navigation

Dr G Satheesh Reddy, Distinguished Scientist & Director, Research Centre Imarat, DRDO has been conferred with the prestigious Fellowship of the Royal Institute of Navigation for his significant contributions in the fields of inertial and satellite-based Navigation and avionics technologies. Dr Reddy is the First and the only one to be elected from India.

KCS TraceME

LoRa ™ Internet of Things

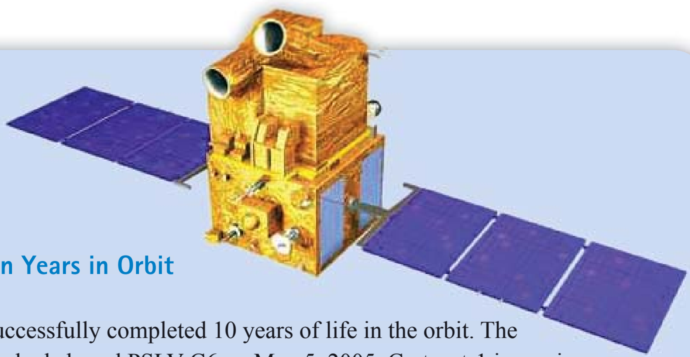
KCS has extended their successful TraceME product line with an advanced module, targeted for worldwide mobility in the Internet of Things era. The latest development of the TraceME GPS/GPRS Track and Trace module will combine the RF location based positioning solution with the LoRa™ technology. This combination offers 'smart objects' being even smarter, since LoRa™ enables long range, battery friendly communication in a wide variety of (M2M) applications. Supporting GPRS/SMS and optional 3G, Wi-Fi, Bluetooth LE, ANT/ANT+ and iBeacon™ provides easy integration with existing wireless networks and mobile apps. Other variants in the high/mid-range and budget-line will follow soon.

ANTI-THEFT module based on RF

KCS TraceME product line offers an intelligent location based positioning solution for indoor and anti-theft applications.The solution is based on RF with an intelligent algorithm of measuring the propagation time of transmitted (proprietary protocol) signals. Unique features are: minimum size (46x21x6.5mm), weight (7 grams for fully equipped PCB) and a standby battery lifespan of more than 10 years.'Listen before talk' algorithm makes it practically impossible to locate the module, which secures the valuable vehicle or asset. Supporting GPRS/SMS and optional 3G, Wi-Fi, Bluetooth LE, ANT/ANT+ and iBeacon provide easy integration with existing wireless networks and mobile apps.

www.Trace.ME

Cartosat-1: Ten Years in Orbit



Cartosat-1 has successfully completed 10 years of life in the orbit. The satellite was launched aboard PSLV-C6 on May 5, 2005. Cartosat-1 is a unique stereoscopic mission with the capacity of acquiring along track stereo images with fixed B/H ratio. Its data is used widely by National and International community for applications related to infrastructure, urban Development, Forestry, Watershed analysis etc. It has also supported the international requirements through the International Ground Stations (IGS). Cartosat-1 scientific Appraisal Programme (CSAP) has published various reports / papers showcasing the Cartosat-1 standards vis-a-vis international standards / data.

international network, corresponding data, start-up funding, and other support valued at more than EUR 300,000 in total. The tremendous amounts of data produced by the European Earth observation programme Copernicus and its Sentinel satellites hugely benefit science and public authorities and open the door to countless products and applications in a wide array of business sectors. The European Space Agency (ESA) and Anwendungszentrum GmbH Oberpfaffenhofen (AZO) have thus initiated the Copernicus Masters competition to aid visionary entrepreneurs in bringing their innovations to market. *www.copernicus-masters.com*

ISRO and CNES MoU

A MoU was signed recently between Indian Space Research Organisation (ISRO) and French National Centre for Space Studies (CNES) on the Indo-French Megha Tropiques satellite which was launched on board the Indian launch vehicle PSLV on October 12, 2011. The MoU shall extend by two more years, the joint project for sharing and use of data from the satellite.

iX Capture 2.0 software by Phase One

Phase One Industrial, manufacturer of medium format aerial photography equipment and software solutions has released Phase One iX Capture 2.0, a control, capture and RAW conversion application designed specifically for aerial photography. Features include support for up to six cameras, Auto Exposure mode and Offline processing of files and complete folders. *http://industrial.phaseone.com/downloads.*

First high res satellite imagery base map of Africa by DigitalGlobe

DigitalGlobe, Inc. has announced the general availability of its Basemap +Vivid product for the entire African continent. Keeping pace with the rapid evolution of mapping technology, this is the first time that a complete, consistent satellite imagery base layer with 50 cm ground resolution has been available for Africa.

This Africa base map strives to maximize consistency and completeness of the imagery, aligning to DigitalGlobe's A3C quality program. Whether zoomed out to view an entire country, or zoomed in all the way down to view local vegetation, dwellings, and infrastructure, the imagery looks the way a user expects the earth's surface to look. *www.digitalglobe.com*

South Africa to launch EO satellite

According to chief executive of the South African National Space Agency (Sansa), South Africa will launch its latest earth observation satellite in 2019. At the moment, the country is reliant on international satellites for information about its 1.2-million km² area, excluding its oceans. *http://mg.co.za/*

Airbus Defence and Space selected by CNES to build MERLIN

Airbus Defence and Space has signed a contract with the French space agency (CNES) to build the platform and carry out final integration of the MERLIN (Methane Remote sensing Lidar mission) satellite.

From 2020 MERLIN will measure methane (CH_4), one of the main greenhouse gases, in the Earth's atmosphere. Using its LIDAR (Light Detection and Ranging) instrument, MERLIN will "probe" the atmosphere to determine the varying concentrations of methane, which, together with carbon dioxide (CO_2), is one of the main contributors to the greenhouse effect.

New countries line up to India for satellite launches

While the Indian Space Research Organisation (ISRO) has put the country in global limelight because of its low-cost mission to Mars, its commercial wing, Antrix, has started witnessing a robust growth with more countries approaching it with offers to launch their satellites.

One such proposal of commercial satellite launch is due for June this year in which three DMC-3 earth observation satellites along with one micro and one nano satellite built by UK's Surrey Satellite Technology (SSTL) will be launched into space.

The mission is designated as PSLV-C28/ DMC-3 which has been taken under a commercial agreement between Antrix Corporation Limited and DMC International Imaging (DMCII), a wholly-owned subsidiary of SSTL. *http://www.hindustantimes.com/*

Bagalkot to have third KSRSAC centre in State

After Mysuru and Kalaburagi, Bagalkot became the third district in the State to have a regional centre of Karnataka State Remote Sensing Application Centre (KSRSAC) for the precise recording of data of land related activities.

Summit UAS OneButton Bundle

DAT/EM Systems International and Icaros, Inc. has announced the release of a collaborative software solution that processes and analyzes Unmanned Aerial Systems (UAS) data. By combining OneButton™ by Icaros and Summit UAS™ by DAT/EM Systems International, UAS enthusiasts will be able to derive valuable 3D information from their UAS-collected data. The Summit UAS™ OneButton™ Bundle requires no training in photogrammetry and is tailored to produce resource-grade data processing and analysis.

Topodrone-100

DroneMetrex has announced that unsurpassed NIR mapping data were captured with the TopoDrone-100. It is for the first time in the UAV's mapping history that such high quality Near Infra Red (NIR) imagery was captured!

DroneMetrex offers their Extended Spectrum Mapping (ESM) camera modification as an option with the TopoDrone-100. After ESM modification, the camera is supplied with 3 external screw-on lens filters. Using simultaneously the NIR filter and also high accuracy L1/L2/L5/GLONASS/COMPASS(BeiDou-2) PPK Direct Georeferencing Solution the TopoDrone-100 captures 3-band imagery, with the near infra-red band recording unparalleled radiometric quality and chlorophyll discrimination. *dronemetrex.com*

Airspace surveillance and sense-and-avoid tool for UAS by Exelis

Exelis has launched its first airspace situational awareness tool designed specifically for unmanned aerial system (UAS) operations in the US. Symphony® RangeVue™ puts real-time Federal Aviation Administration (FAA) surveillance data, flexible background maps and weather information in the hands of UAS operators and test range personnel. The system provides significant improvements to the safety and efficiency of UAS operations, whether on the test range or in the field. It enables to have access to both real-time and historical surveillance information via a Web-hosted platform, helping to manage mission operations from multiple locations with full visibility of assets. *www.exelisinc.com/symphony.*

ISU receives grant for project with J.R. Simplot Company to use UAS

Idaho State University received a $179,000 grant from the state's Idaho Global Entrepreneurial Mission (IGEM) to pursue a project with the J.R. Simplot Company to use unmanned aircraft sensors (UAS) to improve agricultural field productivity and grower profitability.

IGEM's mission is to create new enterprises and high-paying, knowledge-based economy jobs by increasing strategic areas of research and development through targeted partnerships among industry, higher education and government that leverage new and existing resources. *http://www.isu.edu/headlines/?p=7921*

Chicago man lands first FAA exemption in state to fly drone for aerial photography

Chicagoan Colin Hinkle received word this month that he's allowed to fly small drones, becoming the first in Illinois to be granted permission - under Federal Aviation Administration rules - to launch the small aircraft for his aerial photography business. The FAA is on the cusp of implementing new rules and regulations for the operations of the unmanned aircraft, including drones. *http://www.redeyechicago.com*

Rohde & Schwarz Used to Test ERA-GLONASS Systems

The Rohde & Schwarz CMW500 is being used to test the ERA-GLONASS system.

The Certification Center Svyaz-Certificate in Russia is now using the R&S CMW500 to certify ERA-GLONASS systems in line with the TR CU 018/2011 technical guideline. The independent Russian test lab is currently the only test lab in Russia accredited to certify these systems. The R&S CMW500 is a wideband radio communication tester.

Equipped with the R&S CMW-KA095 application software, the R&S CMW500 meets all requirements for testing ERA-GLONASS systems and provides reliable, reproducible tests in line with the Russian GOST R 55530 specification, Rohde & Scwarz said. In addition, the R&S CMWrun sequencer software (R&S CMW-KT110) makes the test solution fully automated and user-friendly.

NovAtel announces RELAY™ RTK Radio Module

NovAtel has launched Relay RTK radio module, a docking station that provides radio connectivity for its SMART6-L™ L-band capable GNSS receiver. The Relay RTK module combined with NovAtel's SMART6-L receiver creates a compact, easy to integrate positioning solution. It is available in four radio versions: 400 MHz UHF licensed band; 900 MHz UHF unlicensed band; HSPA (3G) cellular; and CDMA (1xRTT/EV-DO) cellular. The CDMA version is approved for use on the Verizon cellular network.

The 400 MHz and 900 MHz versions support both base and rover configurations. The base station is easily configured via the integrated web-server/Wi-Fi access point using the web browser on any compatible personal computer, tablet or Smartphone. The cellular radio versions support the reception of NTRIP and RTK corrections over the cellular network. *http://www.novatel.com*

Trimble News

Trimble expands product line for surveyors

Trimble has expanded its portfolio of geospatial solutions for surveyors, engineers and mapping professionals. Highlights include new total stations, a new GNSS receiver and new field and office software features.

"Trimble's portfolio expansion will enable our customers to work in a more efficient, seamless and collaborative manner. Trimble's solutions are best known for quality, dependability and performance. Our vision is to equip customers with the most innovative tools, which includes a focus on offering new software applications that streamline and elevate the value of geospatial data to guide smart decision-making and transform the way organizations work," said Chris Gibson, Vice President of Trimble. The expanded portfolio of productivity solutions include: the Trimble® S5, S7 and S9 total stations, updated version of Trimble Access™ and Trimble TX8 3D laser scanner with greater accuracy.

Trimble Partners with Microsoft

Trimble will be working with Microsoft to develop a new generation of tools, integrated with the HoloLens holographic platform on Windows 10, which are intended to improve quality, collaboration and efficiency in the design, construction and operation of buildings and structures. *http://www.trimble.com*

Hemisphere GNSS RTK-Capable GNSS Compass Smart Antenna

Hemisphere GNSS has announced a top-of-the-line, RTK-enabled Vector V320 GNSS Compass. The first of its kind, the Vector V320 smart antenna supports multi-frequency GPS, GLONASS, Galileo (future firmware upgrade required), and BeiDou. It is the only multi-frequency, multi-GNSS, all-in-one smart antenna capable of both RTK-level positioning accuracy and better than 0.2° heading accuracy in a simple-to-install package. *www.HGNSS.com*

Applanix unveils new Marine Product Portfolio

Applanix has introduced a new and expanded portfolio of Marine georeferencing and motion compensation solutions designed to deliver best-in-class performance at a variety of price points. The new line-up of marine products offers high-performance solutions to a broader cross-section of the hydrographic survey industry. All Applanix Marine products benefit from the optimal integration of GNSS and Inertial observables, with access to Trimble® GNSS technology affording unique performance advantages. *www.applanix.com*

Tallysman GNSS Antennas with Accutenna™ technology

Tallysman has announced that its range of antennas featuring proprietary Accutenna™ technology is optimised for today's multi-constellation satellite systems, including for the Galileo, BeiDou, GPS, GLONASS and IRNSS. *tallysman.com*

Navy Awards $30M GIS Surveying Contract

The U.S. Navy has awarded NAVGeo LLC a $30 million contract to provide GIS, surveying and mapping services.

NAVGeo is a joint venture between national geospatial firms Woolpert, Magnolia River and Quantum Spatial. This is the first Navy contract for NAVGeo, which was formed in 2012. *www.prweb.com*

BVR Mohan Reddy elected as Chairman of NASSCOM

National Association of Software and Services Companies (NASSCOM), India announced that the Executive Council has elected Mr. BVR Mohan Reddy, Founder and Executive Chairman, Cyient Ltd. (formerly Infotech Enterprises) as the Chairman of NASSCOM for 2015-16.

Septentrio announces the AsteRx4

Septentrio has launched AsteRx 4 OEM. It is a multi-frequency, dual antenna receiver which incorporates the latest innovative GNSS tracking and positioning algorithms from Septentrio; offering users in the marine, machine control and agricultural industries precision, accuracy, reliability and ease of use. It offers robust positioning scalable from meter to centimetre accuracy. Together with precise heading and reliable error estimates, the AsteRx 4 OEM functions in the toughest conditions whether on land, at sea or in the air. *www.septentrio.com*

Spectracom Adds IRNSS and QZSS to Simulator Capabilities

Spectracom has added capability to simulate India's global navigation satellite system, IRNSS, and Japan's regional satellite system, QZSS, to its GSG-6 Series multi-frequency GNSS signal simulator. The simulator is designed to be field upgradeable to simulate all current and future GNSS constellations so current customers can benefit from these features without the need for a factory return in most cases.

Prinoth strategic partnership with Leica Geosystems

Operators of ski slopes are facing new challenges to save natural resources used in slope preparation. Two best-in-class manufactures have strategically partnered to improve the ecological footprint of ski areas. Leica Geosystems has collaborated with Northern Italian based company Prinoth, a leading producer of snow grooming machines and tracked utility vehicles, to provide more efficiency in grooming slopes, dramatically reducing fuel emissions and reducing costs considerably. Prinoth has chosen iCON alpine 3D machine control to its new snow groomers to be used in preparation of ski slopes starting this winter season. *www.iconalpine.com*

First BeiDou CORS Station in Europe by ComNav and CGEOS

A BeiDou continuously operating reference station (CORS) station, reportedly the first such commercial venture in Europe, has begun operations in Wallonia, Belgium.

Built by CGEOS – Creative Geosensing (CGEOS), Belgium, in partnership with Chinese GNSS OEM receiver manufacturer, ComNav Technology Co., Ltd., the "QIAO" CORS installation can track the three frequencies of the BeiDou Navigation Satellite System (BDS) and transmit observation data in RTCM format in real time through NTRIP and in RINEX format. These transmitted data enhance the positioning performance of GNSS receivers by combining BeiDou differential corrections with GPS and GLONASS signals.

Eelink launches waterproof GPS Vehicle Tracker TK 119

Eelink has launched new vehicle GPS tracker TK119 waterproof GPS/ Glonass. The latest Waterproof Vehicle GPS tracker encompasses huge range of civil & industrial applications.

The waterproof level of the product is IP67 and the new vehicle tracker supports with many other functions such as ACC detection & remote power cut-off. TK119 caters to a wide range of industries including logistics, oil companies, car rental firms, vehicle maintenance & repair portals, telecommunication, power companies, insurance, vehicle management, SMEs and individual owners.

Telit GNSS Module Enables High-performance Position Reporting and Navigation Solutions

Telit Wireless Solutions has released new GNSS module, the SE868-V3. It combines GPS, Glonass, Beidou, Galileo, and SBAS which enables the creation of high-performance position reporting and navigation solutions.

It can navigate to -162 dBm and track to -166 dBm, thereby providing improved performance in harsh environments. It is pin-to-pin compatible with the former SE868-V2 as well as the JF2. The 11 x 11 mm QFN package contains a powerful baseband processor, SQI Flash memory and GNSS chip with integrated Low Noise Amplifier (LNA). The ultra-sensitive RF front-end enables multi-GNSS indoor fix and hi-quality navigation in challenging outdoor scenarios such as dense urban areas. *Telit.com*

u-blox CAM-M8C GNSS positioning module

u-blox has announced the CAM-M8C, a small, low profile GNSS positioning module with an integrated wideband chip antenna for reception across the entire L1 band. It offers simultaneous GNSS operation for GPS/GLONASS, GPS/ BeiDou, or GLONASS/BeiDou to deliver accurate, jamming-resistant and reliable positioning anywhere in the world. It integrates a u-blox M8 satellite receiver, crystal oscillator, SAW filter and low-noise amplifier. It also has an input for an external active antenna and when using this option the internal antenna acts as a backup. *www.u-blox.com*

FAA Awards New GPS WAAS Contract to Raytheon

The Federal Aviation Administration (FAA) has awarded a $103-million contract to the Raytheon Company to maintain the GPS Wide Area Augmentation System (WAAS). The company will develop a payload to be incorporated into a new geostationary satellite and two associated ground uplink stations to support the WAAS system within U.S. airspace. WAAS improves real-time GPS accuracy from 10 meters to about two meters by transmitting differential corrections as well as integrity messages and an additional ranging signal.

CHC Introduces LT500 Series GNSS Handheld

CHC has announced the availability of the LT500 series of handheld GPS receivers. The LT500 series LT500N / LT500T/LT500H covers three accuracy ranges from sub-meter to centimeter accuracy and is the most cost-effective full GNSS positioning solution for Survey, Construction and GIS professionals.

Powered by the Windows® Embedded Handheld 6.5 operating system, the LT500 is accurate, rugged and versatile. User productivity is greatly enhanced with the built-in gyroscope, an innovative laser plummet for positioning the accurate hand-held receiver over a point, an E-compass for showing the direction and G-sensors for leveling.

Customers will benefit from the competitive price of LT500 series and the wide range of bundled software solutions including SurvCE, DigiTerra, MapCloud and other third-party software.

Topcon news

New total station

Topcon Positioning Group has announced the latest addition to its line of reflectorless total stations for the construction and mining market — the GPT-3500LNW. It is designed to measure further than any non-prism instrument in its class. Along with its onboard data collector, it can connect to an external field controller via built-in Bluetooth® technology, enabling field to office connectivity with the MAGNET® suite of software solutions.

New millimeter GPS laser transmitter

The LZ-T5 Millimeter GPS is an exclusive Topcon technology that allows traditional GPS measurement and machine control systems to improve its vertical accuracy by up to 400 percent. It uses patented zone-beam laser technology to continuously provide high accuracy elevation information to improve GNSS positioning. *www.topconpositioning.com*

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June 2015

ESNC & Copernicus Masters 2015
15 April to 13 July
www.esnc.eu, www.copernicus-masters.com

HxGN LIVE Las Vegas 2015
1 – 4 June
Las Vegas, Nevada USA
http://hxgnlive.com/las.htm

Bentley CONNECTION Event
9th - 10th June
Chennai, India
http://connection.bentley.com

4th World Geospatial Developers Conference (WGDC 2015)
10 - 11 June
Beijing, China
http://wgdc2015.3snews.net/en/

TransNav 2015
17 - 19 June
Gdynia, Poland
http://transnav2015.am.gdynia.pl

The Commercial UAV Show Asia 2015
30 June - 1 July
Singapore
www.terrapinn.com/exhibition/commercial-uav-asia/index.stm

July 2015

IGNSS 2015
14-16 July
Queensland, Australia
www.ignss.org

Esri User Conference
20 – 24 July
San Diego, USA
http://www.esri.com/events/user-conference

13th South East Asian Survey Congress
28 – 31 July, Singapore
www.seasc2015.org.sg

August 2015

The Fifth Session of the UN-GGIM
3-7 August
United Nations Headquarters, New York, USA
http://ggim.un.org

CPGPS MIPAN'2015
26 and 28, August
Xuzhou, Jiangsu, China
www.cpgps.org/new_site/news2015.php

UAV-g 2015
30 August - 2 September
Toronto, Canada
www.uav-g-2015.ca

ESA/JRC International Summer School on GNSS 2015
31 August - 10 September
Barcelona, Spain
http://congrexprojects.com/2015-events/15m21/registration

September 2015

GIS Forum MENA
6 – 9 September
Abu Dhabhi, UAE
http://gisforummena.com

InterDrone
9-11 September 2015
Las Vegas, USA
http://www.interdrone.com/

ION GNSS+
14-18 September
Tampa, Florida, USA
www.ion.org

INTERGEO 2015
15 – 17 September
Stuttgart, Germany
www.intergeo.de/intergeo-en/

October 2015

Commercial UAV Expo
5 - 7 October
Las Vegas, Nevada, USA
www.expouav.com

DIGITAL EARTH 2015
October 5-9
Halifax, Canada
www.digitalearth2015.ca

20th UN Regional Cartographic Conference for Asia and the Pacific
5-9 October
Jeju Island, Republic of Korea
http://unstats.un.org/unsd/geoinfo/RCC/

Intelligent Transportation Systems: 22nd ITS World Congress
5 - 9 October
Bordeaux, France
http://itsworldcongress.com

Geo Empower Africa Summit
6 - 7 October
Johannesburg, South Africa
http://itc.fleminggulf.com/geo-empower-africa-summit

36th Asian Conference on Remote Sensing
19 - 23 October
Manila, Philippines
www.acrs2015.org

2015 IAIN World Congress
20 – 23 October
Prague, Czech Republic
www.iain2015.org

Joint International Geoinformation Conference
28 - 30 October
Kuala Lumpur, Malaysia
www.geoinfo.utm.my/jointgeoinfo2015/index.html

November 2015

ISGNSS 2015
16 - 19 November
Kyoto, Japan
http://www.isgnss2015.org/


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