# MULTI-INTERVIEW (1)

# GNSS and Hydrography

None of us can anymore imagine hydrographic work without satellite positioning. Improvements in performance since the first launch at the end of the70s have made it suitable for more and more applications and developments are ongoing. A GPS modernisation programme is upgrading both satellite performance and ground infrastructure, the Russian Glonass modernisation programme will upgrade performance to GPS level, Galileo test satellites GIOVE A and B are performing well and due to become available in a few years, and there is increasing augmentation system coverage. Time for Hydro International to question some experts on these developments in relation to our profession. We talked to the above and found them all extremely enthusiastic in their response. So much so that space limitations force us to publish this multi-interview in two parts, the second to appear in November.

HI: What new opportunities can the hydrographic surveyor expect from developments in GNSS over the next few years?

**Chisholm**: With a greatly expanded satellite constel lation and enhanced signals, hydrographers will enjoy greater availability, better accuracy and higher solution integrity.

**Cross**: Exactly how GNSS will develop over the next few years will depend on a number of factors, mostly related to political, business and infrastructure issues. We know that there will be more satellites and that there will be more signals. We can also anticipate new augmentation schemes, improved error prediction, significantly better sea-surface models, and advances in GNSS receiver hardware and software. Probably the only uncertainty is the rate at which these will happen and the mechanism through which the enhancements will be delivered to offshore and other users. So the opportunities for hydrographic surveyors are all of those that will come with increased accuracy and integrity of three-dimensional positioning to support the whole range of hydrographic surveying activities. Also, we can expect improved (cheaper, smaller and more accurate) GNSS-based attitude systems as phase noise, especially that due to multipath, is reduced with the new signals, and we can expect to move to more or less entirely real-time operations, with post-processing only being needed for very special applications. I believe that the result will be a more or less on-demand and inexpensive positioning and attitude capability that will be an order of magnitude better than the sensors they are required to support. This will put the pressure firmly on the manufacturers of other sensors, especially under-water acoustic systems of all types, to match the accuracy obtainable on the surface so as to achieve a similar accuracy for mapping the seabed.

**Goodman**: Shore-based RTK systems reaching further offshore, and wide-area augmentation systems such as Starfix-HP providing x,y,z accur-
acies of a few centimetres globally. The use of augmented GNSS for accurate, real-time tidal height determination. Improved reliability and availability of positioning/navigation and, indirectly, improved meteorological modelling and weather forecasting.

**Grognard**: New GNSS developments are leading to more powerful GNSS receivers that are tightly integrated with other non-GNSS receivers. Like in other professional segments, the hydrographic surveyor can expect increasingly more robust and better equipment.

HI: Over the coming decade the combination of GPS, Glonass and Galileo is expected to deliver accuracies of 1dm in standalone mode. Will we still require a differential solution?

**Chisholm**: Galileo is expected to provide a global differential correction signal within its navigation message. This service will most likely be offered in modernised GPS, and possibly Glonass. Even with enhanced navigation signals, differential services will provide a higher level of integrity monitoring and greater accuracies at faster initialisation times with these corrections services and signals. Centimetre-level RTK techniques are likely to have an extended operating range and will therefore become commonplace for many hydrographic applications.

**Cross**: The delivery of global decimetre accuracy is technically possible today in what might be called 'standalone' mode; in other words, without the explicit use of data from base-stations, although data from a global network of base-stations is needed to drive the models necessary to do this. This accuracy has been demonstrated by a number of experiments and can be expected to improve by an order of magnitude as new GNSS signals come on line. Therefore it's pretty easy to see that if one defines differential GNSS as involving the direct combination of data from a mobile and one or more base-stations, then within ten years it will be completely redundant for almost all offshore hydrographic applications. There may, however, be specific local applications for which differential solutions may have a role;

these are likely to be for high-accuracy applications that also require a very high level of integrity, usually safety-critical or legally-critical applications.

**Goodman**: The original differential GPS (DGPS) systems used GPS receivers located at accurately co-ordinated monitoring stations to measure the systematic errors and random errors, such as Selective Availability, in the GPS system without necessarily separating one source of error from another. Todayâ€™s DGPS systems are more sophisticated, partly thanks to the removal of Selective Availability, in that they are better able to distinguish between the various sources of error. They do so by analysing the measurements from a network of monitoring stations and communicating the error corrections to hydrographers and other users by a variety of means. The term 'differential GNSS' (GPS and Glonass) is gradually being overtaken by the term 'GNSS augmentation', to better describe the use of a network of monitoring stations to determine the various systematic errors in these systems.
I do not agree with the statement that 'standalone' GNSS, (without supplementary augmentation), will provide decimetre-level accuracy simply by combining GPS, Glonass and Galileo. The various systematic errors inherent in these systems will still need to be reduced, if not eliminated, requiring a network of ground-based monitoring stations to determine these errors and a means to feed this information back to the user in real-time. So whether GNSS augmentation is 'integrated into' one or other future GNSS service or it is left to independent companies like Fugro to provide a network of monitoring stations, communications infrastructure and control centres, GNSS augmentation will certainly be required to achieve 1dm accuracies globally in real time. This is a service already offered today by Fugro.

**Grognard**: The main reason why differential techniques shall still be needed is the attractiveness of single-frequency equipment, both receivers and antennas, for the sake of simplicity of design, low power consumption and cost. For single-frequency receivers, differential corrections shall be required to correct for ionosphere delays, even with dm-level system biases. Please note that L1 frequency band is common for all the systems, so single-frequency equipment shall always remain relatively simple. On top of that, one should remember that RTK positioning with fixed ambiguities, which shall remain the most accurate positioning technique for a very long time, essentially requires differential processing.

HI: For which applications will a differential solution still be required and what 'differential' techniques and delivery methods can be expected?

**Chisholm**: For accurate offshore positioning, the use of satellite-based GNSS differential correction services from a greater variety of suppliers will be an increasing trend. For the most precise uses of GPS (3D centimetre) such as marine construction, a localised supply of corrections from ground-based systems is needed, and these could be via radio links or cellular delivery for near-shore projects. The WiFi (802.11) delivery medium is also starting to become useable for near-shore marine operations.

**Cross**: As I have explained, I don't believed that differential solutions, in the sense of differencing raw GPS data collected at mobile and base-stations, will have a significant future role in hydrographic surveying. I do, however, believe they might continue to be used in some very high-accuracy, safety-critical applications, such as manoeuvring vessels in ports and very congested waterways, not so much for the greater accuracy that will be obtained as for the increased local control over the integrity. With such systems the differential-system providers and users can be provided with a local guarantee of fitness for purpose.

**Goodman**: Based on the specifications for Galileo and the published enhancements planned for GPS and Glonass, I believe that the standalone, or non-augmented, accuracy attainable by combining these systems will be in or around the 1m level (95%). Anyone needing a higher accuracy than this in real time will require access to an augmentation service, whether bundled as an integral part of a GNSS or an independent augmentation service like the one Fugro currently provides and will continue to provide using all available GNSS satellites. Future state-of-the-art GNSS augmentation systems will go further in breaking down and correcting the systematic error components and sub-components than we do today, thus improving the accur-acy and reliability of these systems. Future GNSS may well support the transmission of augmentation data to hydrographers, and other users, via the satellites themselves, while independent GNSS augmentation service-providers will certainly avail of any new mobile communications systems which emerge in the coming years.

**Grognard**: Phase-differential solution provided by RTK or in post-processing is used when guaranteed cm-level accuracy is required. The main role of high-precision GNSS-based positioning in hydrographic surveys is to provide a vertical reference datum for the depth measurements. Surveying of shore controlling points, measuring of tidal heights and airborne Lidar hydrography are typical examples of applications where high precision is needed. In the coming years we shall also see increasing use of GNSS-based heading/attitude determination systems for navigation of hydrographic vessels; these systems are essentially based on phase-differential processing.

HI: Hydrographers are interested not only in horizontal accuracy but in vertical accuracy as well; for ex-ample, for online tidal reduction/information. Can you give estimates of the areas and accuracy we as hydrographers and in general shipping can expect, and when?

**Chisholm**: The very nature of satellite positioning means that the height component has the greatest uncertainty. Multipath, tropospheric bias and weak satellite geometry all degrade the height accuracy achievable with GPS today. With full constellations of GPS, Glonass and Galileo, and an unobstructed view of the sky, it will be commonplace to have twenty to thirty satellites above the horizon at any one time. Improved satellite geometry not only reduces Dilution of Precision (DOP): it also aids estimation of tropospheric and other bias parameters. Modernised GPS signals and Galileo will have advanced code structures that allow for greater suppression of multipath effects and improve vertical accuracy.

**Cross**: There are many reasons why GNSS currently delivers vertical accuracies that are typically twice as bad as those in the horizontal directions, especially, in the case of differential operations, far from base-stations. The dominant reason, however, is related to our inability to model atmospheric errors which lead to ranges being systematically too long or too short, and since all satellites are above us there is no possibility of averaging. The good news for the future is that with large numbers of satellites in view there is the possibility of solving parameters for a much more sophisticated model of the atmosphere in the vicinity of the mobile than is currently the case. I still expect horizontal GNSS accur-acies to be better than their vertical counterparts, but I believe the gap will close. So I fully expect to see global single-centimetre accuracy from a fully augmented, combined future GNSS system. This will put enormous pressure on the production of very high-accuracy global sea-level and tidal models; simple co-tidal charts are unlikely to be sufficiently accurate. This is something that is happening in some parts of the world. For instance, at UCL we are undertaking a project for the UK Hydrographic Office to do this for the waters around the UK. It is a complex problem, involving the analysis of hundreds of tide-gauge records, precise geoid models, GPS data and sea-surface topography obtained from satellite altimetry.

The ability to obtain heights of vessels relative to the seabed is of enormous commercial importance. Very high-accuracy GNSS, with accurate seabed models and accurate sea-surface models, are crucial for the navigation of large vessels in most of the world's ports. Significant savings can be made if vessels do not have to wait unnecessarily for high tides before travelling along shallow channels, and such knowledge could also be used to optimise future dredging operations.

**Goodman**: Standard RTK systems already achieve 4-6cm (95%) in vertical accuracy. This can be improved to 2-3cm by better multi-path reduction. While the range of RTK systems will be extended thanks to an increased number of satellites and signals, the range of RTK will remain a limitation for the offshore hydrographer. The Starfix-HP long-range augmentation service currently provides a vertical accuracy of better than 20cm (95%). This should improve to the 5-10cm level as certain planned GNSS enhancements become available.

**Grognard**: Vertical accuracy provided by GNSS has always the same order of magnitude as the horizontal accuracy, although for standalone positioning it is normally worse by a factor of 1.5 to 2, due to well-known reasons related to geometric factors.

Editor's Note:
In the second part of this interview, to be published next month, our interviewees give their views on the possibilities/advantages of the many signals becoming available as developments continue and discuss other matters, including GNSS services.