First AGPS — Now BGPS

Instantaneous Precise Positioning Anywhere

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GOOD NEWS, EVERYONE! Instant GPS positioning appears to be at hand. For better or worse, we live in fast-paced society with its fast food, fast communications, and fast cars, and have come to expect instant responses when we want something. Our TVs now turn on instantly. We push a single key on our mobile phones for speed dial or instant push-to-talk service. We press the shutter on our digital cameras to capture and view images instantly. But GPS? Not so fast.

INNOVATION INSIGHTS
with Richard Langley

BGPS can produce first fixes within one second.

After switching on our receiver, we typically have to wait for some time before we can start navigating. This time to first fix (TTFF) depends on the quality of the received signals and the age of the receiver's stored almanac and ephemerides used to determine the positions of the satellites. It's also affected by how well the receiver knows the exact time. So there are several kinds of TTFF.

If a receiver has no knowledge of its last position, doesn't know the approximate time, and has no almanac, it starts searching for signals blindly. This is called a cold start. Depending on signal quality and the design of the receiver, it can take anywhere from 60 seconds to 12 minutes or more before the receiver acquires signals, obtains ephemeris data, measures pseudoranges, and gets its first position fix.

If the receiver knows the approximate time as well as its approximate position and has a recent almanac but not a current ephemeris, it can produce a position fix within about 30 seconds or so after it is switched on — the time required to receive orbit and clock data from the tracked satellites. This is called a warm start.

A hot start occurs when a receiver is powered on with a current ephemeris (received within the past four hours). It can take up to 6 seconds or more before the first fix as the receiver must typically acquire time marks from the satellite navigation messages to resolve the pseudorange ambiguities.

Assisted GPS, or AGPS, can reduce TTFF by supplying current ephemeris data and accurate time over a mobile phone network. In some situations, TTFF can be reduced to just a second or two. However, the receiver does need to be connected to an AGPS network and so cannot operate autonomously.

Enter BGPS. In this month's column we learn about an innovative approach that can produce accurate first fixes within one second without a network connection. Within one second and without a network connection? Oh my, yes.

"Innovation" is a regular column that features discussions about recent advances in GPS technology and its applications as well as the fundamentals of GPS positioning. The column is coordinated by Richard Langley of the Department of Geodesy and Geomatics Engineering at the University of New Brunswick, who welcomes your comments and topic ideas. To contact him, see the "Contributing Editors" section on page 6.

In an Expert Advice column in the October 2006 issue of this magazine, one of us wrote:

"With hundreds of navigation satellites in the sky, and a handful of GNSS-enabled gadgets, the taxpayer would expect to get the resulting service — his instant position at any time and at any place — without becoming a specialist in satellite navigation. This is our challenge today: providing seamless instant positioning at any location, at any time, at the touch of a button."

Since autumn 2007, we have been pooling our efforts to create the necessary technology, which would enable us to meet these goals. We have now developed a procedure that provides an immediate position fix at the touch of a button. This novel approach has been developed on the borderline between assisted GPS (AGPS) technology and that used for geodetic applications. We used an opportunity to implement this technology to create a software receiver, which meets the requirements of the Japan Aerospace Exploration Agency (JAXA) for an airborne software receiver. JAXA is investigating robust navigation systems for aircraft operation, including precision landing. The software receiver will be used for the development of an ultra-tightly-coupled GPS/inertial navigation system (INS) unit to cope with ionospheric anomalies and interference. This project also allowed us to validate the receiver and the associated technology.

For instant positioning, we need to avoid the need of tracking a satellite signal for any length of time and of reading a navigation message. It takes about 30 seconds to read the parts of a GPS navigation message necessary for a position fix. Even if navigation message data is available through some other data link, it is still necessary to decode a time mark from the navigation message in order to resolve the initial 1-millisecond pseudorange ambiguity and to calculate satellite positions at the time of signal transmission. This may take up to six seconds. It is important for many applications to be able to determine a position instantly, using just a snapshot of data.

In his contribution to the May 2006 *GPS World* feature "50+ Leaders to Watch in GNSS," Frank van Diggelen said "… the innovations of the last five years are going to move into the mainstream — ephemeris over the Internet, sub-second time to first fix (TTFF), and the like will become standard." This was the goal for us as well. However, ever since the idea of instant positioning without a navigation message was first introduced by Jari Syrjärinne in 2000, almost all research has concentrated on using network assistance to accomplish this task.

AGPS technology came along with a partial solution to the problem. But the solution is only partial because, first, AGPS requires network access, which is not always possible. Second, AGPS cannot in many cases avoid the necessity of decoding the time mark. And third, usage of AGPS can compromise user privacy. And there are many applications for which AGPS is of no help. Let us look at a few examples.

As we know, it is often impossible to track GPS satellite signals indoors and therefore it is impossible to decode the navigation message, even partially. Moving indoors will change the multipath environment and tracking most likely will be interrupted, even if it was possible in the first place. Using AGPS will help for some indoor applications, but there are many places with obstructed satellite views, where an AGPS network is not available. Just think about positioning in the "back woods."

When using the GPS function in some mobile phones, voice calls should not be made at the same time because they can interfere with GPS signal reception. This means that a user has to wait until all the data from the navigation message is acquired before placing a call. AGPS decreases this waiting time to a much shorter but still very noticeable interval — that needed to acquire only one subframe of navigation data to retrieve the time mark. It is often impossible to get time information through a network accurate enough to avoid reading at least one subframe of the navigation message. There is also a privacy issue with AGPS. Users might just wish to navigate themselves without supplying information on their location to the outside world.

Such applications as a GPS-enhanced camera also would benefit from an instant position fix. Users would definitely like to make a shot quickly, and then go about their business, rather than having to wait for at least 30 seconds until needed data in the navigation message is acquired and the position is stamped on the photo. And it is unrealistic to expect that users would always be taking their photos in places where a network is available.

The capability to perform instant positioning without a network is also desirable because networks can malfunction or even be destroyed by natural disasters such as earthquakes. In the aftermath of such disasters, an instant positioning capability is vital for recovery operations.

An aircraft maneuvering in the skies definitely could have difficulties getting an uninterrupted line of sight to a particular satellite. This application for an airborne receiver was especially interesting for us. An ability to use all possible snapshots of data benefits aircraft navigation in two respects. First, no data is lost to a navigation system even if a satellite was in view only for three milliseconds. Second, such data has much lower latency, which is extremely important in the case of high-dynamics vehicles such as aircraft. Needless to say, network assistance most likely will also be impossible for such applications. We have developed a receiver for this application to test and verify the technology to perform instant positioning using a few milliseconds of data. In this article, we will take a look at this promising technology. It may — if properly developed — open doors to hundreds of new applications and even to the possibility of reconsidering our notions of future GNSS signal structure.

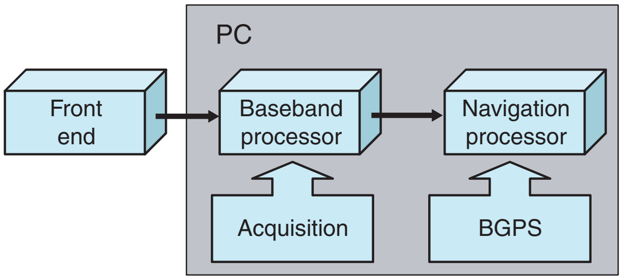
Convergence of Geodesy, Mobile Applications

In the near future, the landscape of positioning with GNSS is going to change drastically. Two streams of GNSS application development, which were until now moving in opposite directions, are coming together at last to provide an ultimate positioning experience.

These two streams are best represented by geodesy and mobile applications. Let us briefly look at their characteristics. They usually seem to have so little in common that people who attend geodesy conferences rarely come to mobile ones and vice versa.

Geodetic applications concentrate on achieving millimeter-level position accuracy, while having the luxury of delayed- or post-processing to achieve it. They use data gathered from many stations all over the world and accurate but instruction-time-consuming models and algorithms in the processing software. Indeed, to estimate one's position with high accuracy, one may need the following information: precise (and accurate) satellite ephemerides; Earth rotation data; ephemerides for the main celestial bodies, such as the Sun, Moon, and major planets; satellite geometry to account for the effect of the Sun's radiation pressure; ionospheric and tropospheric data; and more. Research centers processing data from GNSS networks routinely obtain absolute positions with accuracies of a few millimeters. However, it is much easier to find relative positions with such accuracy. If one can assume that the position of a nearby reference station is accurate enough, then one does not need precise models to find one's relative position with very high accuracy. One also can apply the method of precise point positioning (PPP) to achieve an absolute accuracy of centimeters without direct use of data from other stations, but, again, precise models and essential data on satellite ephemerides and atmospheric errors, compiled and distributed by international services, are required.

Mobile applications, on the contrary, try to provide users with an "instantaneous" position fix in real time. Initially, instantaneous actually meant a time interval of tens of seconds. Subsequently, this was trimmed to seconds. Now we need to produce fixes within a sub-second interval. Mobile applications also require positioning



▲ **FIGURE 1** A block diagram of a PC-based snapshot software receiver, which has been developed to facilitate BGPS technology development and serves as a prototype for an airborne receiver. There are extra tracking loops for the airborne receiver, which are not shown here.

everywhere and under any conditions, including indoors. However the price for this universality and availability is accuracy. It seems to be hard to achieve even tens of meters accuracy instantly and everywhere.

So, what do geodesy and mobile applications have to do with each other? The first thing in common between these two streams is use of external ephemeris information. Indeed, to achieve their requirements, mobile solutions have applied AGPS technology. AGPS uses assist data containing satellite orbit and clock errors delivered over a mobile phone network. Sometimes a GNSS network has to be used to create ephemeris data with longer validity than just two hours of broadcast data. AGPS allows a user to ignore most of the broadcast navigation message. As a result, TTFF has been reduced to six seconds. These six seconds are required to acquire the time mark — the time in GPS System Time when a particular transition in the GPS signal occurs. This time mark is essential, first for calculating pseudorange measurements and, second, for obtaining the correct position of satellites in the sky before determining a position fix. A GPS satellite is moving with a speed of about four kilometers per second. Thus a misalignment of a user's receiver clock in one second gives a few kilometers error in user position. Some mobile phone networks can supply users with accurate time as well. With such a network, if the receiver knows its approximate position (also obtained from the network), it can determine a position fix as soon as it has acquired signals without reading the navigation message at all. Unfortunately, most networks are not able to supply time with the required accuracy.

However, the use of AGPS has some rather significant shortcomings. Among the main disadvantages of AGPS is that it requires use of a mobile phone network. In many places networks are not available, yet the user requires an instant positioning functionality.

Also, it is not possible to simply transmit assist data through any mobile phone network, because this data transmission method is patented.

Another important drawback of AGPS is that AGPS can compromise user privacy. The user has to be connected to a network at the time of positioning. Sometimes it is required to send data to the server. The bottom line is the server always knows where users are when they use AGPS. Of course, the aim of E911 regulations is to force the mobile operators to locate any distress call. But with many AGPS implementations, mobile operators can locate a user every time he or she makes a position fix.

AGPS brought new opportunities to enhance sensitivity, availability, and applicability for mobile applications, by providing orbit and other data to the mobile device. This data can be used to facilitate rapid signal acquisition, to allow a receiver to work in snapshot mode without reading a navigation message, and also to increase signal sensitivity.

Can one keep these exciting advantages without adding network constraints and sacrificing one's privacy? We think that today a new technology, which allows one to enjoy almost all the benefits of AGPS without its shortcomings, has emerged.

BGPS

We tried to find an answer to the following question: can one have AGPS-like positioning without using a network and at the same time without reading a navigation message from a satellite signal? As we've mentioned, a receiver with such a capability would be advantageous: its operation wouldn't compromise one's privacy and one could enjoy all the advantages of AGPS in places without network coverage.

In response to this question, we have developed BGPS. Why "B"? Because it follows "A." It started out as a working title for the project, and just stuck. BGPS is a set of algorithms and methods allowing one to make position fixes without reading a broadcast navigation message or connecting to a network. All required data can be preloaded into the receiver. A real-time software receiver for airborne application has been developed to validate the technology.

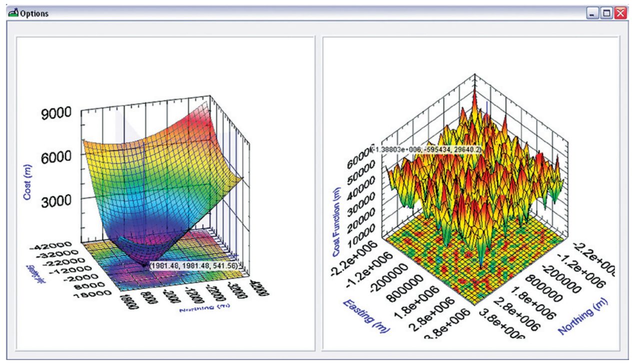
This technology of course does not rely exclusively on a software receiver. Software receivers have become popular in recent years because they can provide lighter, cheaper, and more flexible solutions, especially for mobile applications. **FIGURE 1** presents an outline of the software receiver, dubbed iPRx, that we use for the JAXA airborne receiver application. The block diagram is intentionally simplified by limiting it to essential components. The receiver has a front end with two main functions. It down converts the radio frequency (RF) signal, and then digitizes it. Such a front end is an essential part of all types of receivers. Our front end is a bit more complicated, because it has to accommodate a USB connection to a host personal computer (PC). It also has a field-programmable gate array (FPGA) to provide options for data packing and decimation. It gives a user an extra flexibility to specify sampling rate and data representation of the digitized signal.

The next component block of a receiver depends on whether it is either a software or hardware receiver. For the sake of simplicity, we will look at the software snapshot receiver only. In such a receiver, the digitized data goes directly into the processor.

Two main functions take place in the processor. First, the signal goes through an acquisition process. The outputs of this acquisition process are code measurements, which can be converted into pseudoranges if the receiver has a time mark. Without a time mark, these code measurements are ambiguous. This time mark can come from the navigation message or from assist information. Given the time and the corresponding satellite position derived from the ephemerides, the navigation processor will calculate a user position. In the process, the biased pseudoranges are essentially converted into ranges to the satellites using satellite clock error data, which again can come either from the navigation message or an outside source. The fact that the receiver is a snapshot receiver means that it may not use tracking loops. Tracking loops are used to receive information from the navigation message and to enhance the accuracy of pseudorange measurements. As we can see, it is absolutely necessary to get satellite orbit and clock information along with a time mark to make position fixes. To read the necessary information from the navigation message takes about 30 seconds of usually uninterrupted tracking. Getting rid of the necessity of reading the navigation message is paramount for a number of applications.

Thanks to the tremendous work being carried out by individuals and agencies contributing to the International GNSS Service (IGS), we have easy access to alternative types of ephemerides. One type, in which we were particularly interested, is a predicted one, with a validity of up to five days. The ephemerides consist of two types of data: satellite orbits and satellite clock corrections. Satellite orbits are actually valid for a very long time. Clock errors are more difficult to predict. We are developing software to predict our own ephemerides for several reasons. First, the ephemerides available from the IGS are only valid up to five days and we are interested in a much longer period of validity. Second, if a service is to be provided commercially, the company that provides it will benefit from assuming responsibilities for the service quality and reliability. And third, this development is a part of our efforts to incorporate the ephemeris prediction technology within a user's receiver. It plays to our advantage that the ephemeris service we require is not going to compete in accuracy with the IGS type of service, because it aims to meet the requirements of mobile applications and therefore can be tens if not hundreds of times less accurate.

The other necessary information required from the navigation message is a time mark to place satellites correctly in the sky and to restore code measurements. This represents a limitation to all instant positioning performed without the benefit of synchronized networks. As a result, TTFF is normally limited to the time needed to retrieve this time mark. It takes six seconds to read one subframe of the navigation message and retrieve the time mark. If this time mark is received from the network with an accuracy of a millisecond, then the receiver can resolve time ambiguity and make a position fix. BGPS allows one to retrieve the time of transmission (TOT) from a snapshot of data in real time. It has been known for quite awhile that it is possible to calculate TOT without reading the navigation message, but such algorithms were always excessively demanding in terms of workload and calculation time — sometimes as long as 14 minutes. The reason for that can be illustrated by the appearance of the cost function used in the positioning algorithm. If a program has to search over a few



▲ **FIGURE 2** Example of a cost function, which has been plotted for the AGPS type of algorithm (left) and the BGPS type of algorithm (right). The AGPS solution allows one to put tight constraints on initial time and position assumptions. These figures are screenshots from the first version of our receiver, which was not able to find a position in real time due to the complexity of the cost function.

milliseconds of clock offset and a few kilometers of range uncertainty, then the cost function looks smooth and manageable (see the left plot in **FIGURE 2**). But when the range uncertainty is a few thousands of kilometers and the clock offset is tens of seconds, the cost function becomes difficult to use (see the right plot in Figure 2). Therefore, we have developed an approach — a combination of analytical and computational methods — to achieve real-time operation. Our test receiver has computed TOT within one second of data acquisition without limitations on assumed user position or clock error.

Test Results

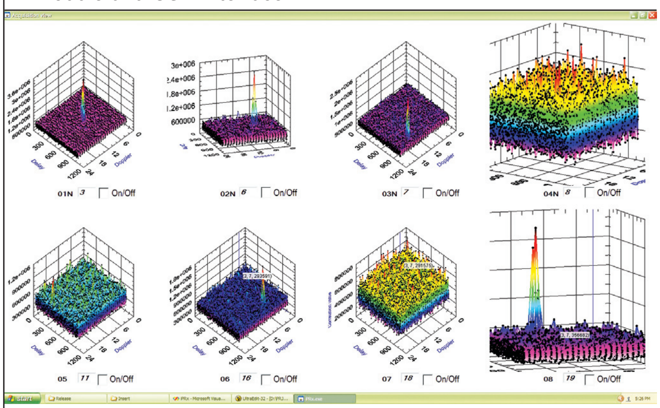
The iPRx real-time software receiver has been tested by JAXA. Those tests allowed us to evaluate and validate the developed technology. We will look at the test procedure, which will also illustrate how the BGPS technology operates on the user side.

First of all, we have to verify that our host computer is reasonably well synchronized. We used a standard off-the-shelf PC for our test and the PC time was not specially adjusted for the test. Though we can allow a large time error, it is still better to have some limitations on it. It is desirable to have PC clocks within a few seconds of UTC. Computer time can be easily corrected using the Internet-based free time servers. PC time also can be automatically corrected using the receiver once a position fix is made.

The next step is to prepare ephemeris information. IGS and its analysis centers provide predicted ephemerides valid for up to five days on their websites. It is possible, however, to create a longer prediction. This data, along with some other data such as Earth rotation parameters, had been fed into the iPRx software receiver and preprocessed to create a special type of orbit and clock information. After that, we can connect the front end to the PC and start immediate positioning anytime within the next five days.

The test was conducted on September 16, 2008, at JAXA's GNSS test facility (see **FIGURE 3**). The facility is housed within a 10-meter-diameter radome, which has a radio transparency of more than 98 percent. For one test, an external GPS antenna was connected to the iPRx receiver. But another test was carried out

▲ **FIGURE 3** Toshiaki Tsujii stands is in front of JAXA's radio-transparent dome test facility and (inset) is shown conducting a test on an iPRx receiver. The box to the right of the laptop contains the iPRx receiver hardware, with an embedded front-end module and USB interface.



▲ **FIGURE 4** A screenshot of the iPRx software window showing acquisition selections. The horizontal axes represent code delay and Doppler shift. The plots are scalable and can be rotated to allow better visualization.

using a mobile-type antenna located on the desk near the receiver. We conducted both TTFF and accuracy tests.

It took less than one second for the PC to accomplish the acquisition process. Acquisition time can vary depending on the PC's specifications, such as type and number of processors and size of RAM memory. The process can be sped up if it is implemented in an FPGA. A 4-millisecond GPS signal sample was acquired. This gave a short acquisition time. It took about another second to calculate a position. The initial assumed position, which had been introduced in order to speed up the acquisition process, was 1,500 kilometers away from the true position. Such an approximate initial position allows the acquisition algorithm to look only for satellites visible in a region centered on this position.

FIGURE 4 shows a screenshot of the receiver program window with acquisition selection. Satellites with pseudorandom noise codes (PRNs) of 3, 6, 7, 11, 16, and 19 were acquired. PRN 11 had poor quality, because it was a low-elevation angle satellite. **FIGURE 5** shows a scatter plot for the 10-minute test with 15-second epochs. The plot in north and east directions is overlapped on a Google Earth map showing JAXA's facility. The receiver outputs its real-time position to Google Earth using a KLM (formerly known as Keyhole Markup Language) file. The true antenna position is pinpointed by a yellow pin. The test showed that the error in horizontal and vertical position was within the E911 specification. In fact, more than 68 percent of the fixes from the iPRx receiver were within 20 meters. The test also showed that TTFF was about 1.5–2 seconds, where about half of this time was taken up by the acquisition process. The accuracy could be further improved by increasing the data sample size and implementing loop tracking.

During some of the tests, we connected the antenna to the front end for less than a second. Actually, a couple of milliseconds is enough to make a position fix. Therefore, the potential TTFF can be as short as a few milliseconds. And we can call this a "cool start" TTFF because we can achieve it after the receiver has been switched off for a few days.

Seamless Positioning Across Applications

After the real-time software receiver with BGPS functionality had been developed, we realized that it is a tool that can combine functionalities, which so far seemed not to go together well. Using GNSS services, the iPRx receiver in fact is collecting all the required information to process data for much higher accuracy. If the orbit and clock information is recent enough, then the receiver can collect data for a longer period and apply PPP techniques to get centimeter-level accuracy. Anybody who deals with surveying or precise positioning knows that precise orbit and clock data are necessary for centimeter-level positioning in standalone mode. This data can be obtained from the IGS, for example, through the Internet. The iPRx receiver uses such data anyway for producing its instantaneous position fix and it becomes clear to us that it can use this data for PPP as well. Such a software receiver could put mobile positioning and surveying into a single product. Naturally, it will take different lengths of time and a different set of algorithms to perform these different tasks. **FIGURE 6** shows conceptually the solution time versus accuracy trade-off. A receiver can give the user a position within one second with an accuracy of tens of meters. This position can be further improved to a meter and sub-meter accuracy within minutes, and then possibly to the centimeter level within hours. These improvements will depend mostly on ephemeris and receiver front-end quality.

Such a receiver could provide users with the ultimate experience. They would have one solution for many tasks. The solution is especially well suited to be incorporated in PC-like mobile devices. Users would have easy access to the required ephemeris data through the Internet and to mapping functionality such as that provided by Google maps. A user would require access to the Internet about once a week or possibly only once a month in the future. Maps could also be stored in computer memory. The software receiver uses BGPS for instantaneous positioning and indoor applications and can use PPP for different professional tasks.

The front end used in our receiver is truly a miniature device with a cost of a few dollars. It is basically the only hardware component, besides an antenna, required for the solution implementation. This hardware front-end module could also serve as the main component for a number of applications. Instead of supplying data to a PC through a USB interface, the front-end module, with a size measured in millimeters, could be combined with memory or a communication device. It could be the basis of a light, cheap, and reliable tool for fleet monitoring, and child, pet, or asset-tracking systems. The user end device could cost just a few dollars and weigh just a few grams. Only a few milliseconds of data need be sent to the server for computing a user position. It is not necessary to compute the position on the user side. In this application, baseband and navigation processors would not need to be implemented on the mobile device.

We have developed two types of front end for the iPRx receiver, shown in **FIGURE 7**. One is a small USB stick for snapshot positioning; the other has an embedded complex programmable logic device (similar to a FPGA) to provide decimation and data repacking to facilitate tracking and digitized data logging. We use an external antenna at this stage for both front ends to ensure quality of the processing software during development. The front-end USB stick was made to create a prototype for an asset-monitoring system. A PC with a USB stick sends collected data to a control center PC through a wireless local area network or the Internet using the Internet protocol suite, TCP/IP (the Transmission Control Protocol and the Internet Protocol). The control center PC has a modified version of the iPRx software, which is able to process data from a few mobile front ends. The data amount is defined by the length of acquired signal and sampling rate. The minimum amount of data is about three milliseconds.

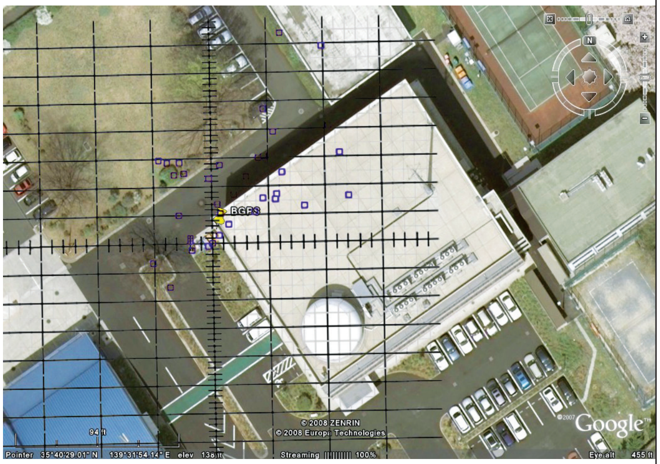
Our main application goal for this project was positioning of an aircraft moving with high speed and dynamics. For aircraft, it is advantageous to be able to make a fix instantly, because the aircraft is moving quickly and any delay may result in large position errors. And that is why a key feature of BGPS is that it works with just a few milliseconds of data. Furthermore, one can be sure that for a maneuvering aircraft no data will be lost, no matter how short the observation interval is.

An even more challenging application is time synchronization. If receiver front ends are incorporated into a sensor network, they may provide excellent time synchronization down to tens of nanoseconds.

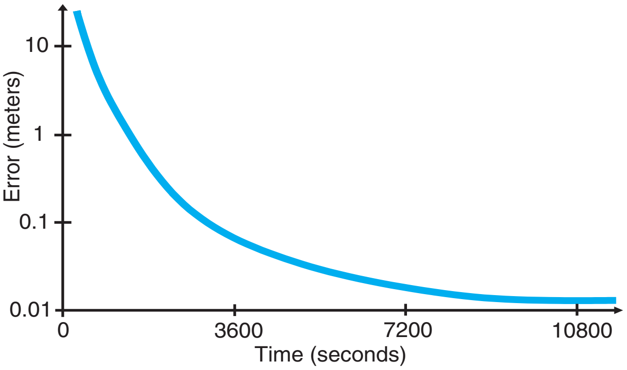
Private vs. International GNSS Services

There are, of course, a number of questions related to the use of data from international GNSS services. Can they be used for commercial services and applications? There are no restrictions at the moment — a policy that perfectly follows the spirit of free use of satellite navigation in general. On the other hand, there is a general understanding that to provide a commercial service, a company has to have its own network. It has been the tendency in recent years for commercial companies to create their own networks to provide ephemeris services to the end-user devices, which employ their technology.

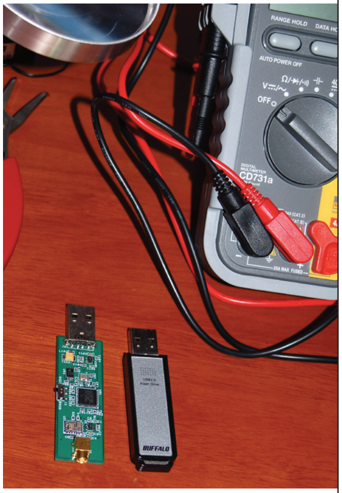
The fact that these companies have their own networks gives some reassurance to a user. A company also has the means to ensure the quality of its products and to take responsibility for them. However, the quality of private network data can hardly compete with that of international service networks because of their size and distribution. It brings up the following question: How many stations globally are required to meet the requirements for predicted ephemerides for mobile users? For less demanding applications, the accuracy requirements are not so strict. In this case the limited size and distribution of a commercial network most likely will suffice.



▲ **FIGURE 5** The output from an iPRx receiver passed to Google Earth. Each large division on the horizontal axis is 10 meters; on the vertical axis, 5 meters. The antenna used for this test is located on top of the JAXA building. A yellow pin depicts the true position of the antenna. Another test was conducted inside the radio-transparent dome, which can be seen in another corner of this building as a large circle.



▲ **FIGURE 6** The approximate relationship between achievable accuracy of standalone positioning and the time required to achieve such accuracy. The regions where the plot converges to the axes represent the biggest challenges.



▲ **FIGURE 7** The USB stick-type front end for the iPRx receiver beside a standard USB memory stick.

However, if a receiver is operating with PPP-like procedures, then it will add other requirements to the underlying network service. It is difficult to conclude at the moment whether private networks can meet those requirements. The accuracy required for ephemeris services to support geodetic applications, such as PPP, is very high. And this restricts the type of data processing required to generate the high-accuracy products. The services often use double-differenced observations from dual-frequency receivers to produce the high-accuracy ephemerides. This type of processing puts some restrictions on the network size. In fact, it is recommended to use single-differenced observations for small networks, which most likely will give less overall accuracy.

Another important factor is that most of the private services probably still rely on some data from the international services. Not raw GNSS data perhaps, but, for example, Earth rotation parameters. This means that these private services are not completely independent.

By the way, for those who may be concerned about using predicted ephemeris data, it is worth mentioning that broadcast data are in fact predicted as well.

Advantages of BGPS

BGPS allows one to use signal snapshots in a mobile device without network connections.

The receiver position is calculated in real time using only the pseudoranges derived from the snapshot and stored ephemerides. The fix can be produced instantaneously — within parts of a second.

BGPS technology could successfully replace AGPS in many applications, especially those which cannot easily connect to a network or in which the network is not synchronized with sufficient accuracy. BGPS uses global products that are not localized. Users can download products in the United States, then go to Japan and switch on their receiver almost a week after they downloaded the data and get a position fix within parts of a second. BGPS doesn't require assistance data more than twice a week as of today, and we see ways that we can prolong data validity to much longer periods. All privacy concerns raised by AGPS are resolved with BGPS. Furthermore, BGPS technology is applicable to any GNSS signal, whether it comes from GPS, GLONASS, Galileo, or QZSS.

The iPRx receiver requires predicted ephemeris information, ionosphere information, and estimates of some geodetic parameters, at least once every four or five days. This information can be derived from data freely available from international services, such as the IGS. We are now working on creating relatively independent data sets. The basic geodetic information, such as that related to Earth rotation parameters, will still be based on data from international services. This information has a very long term of validity.

This technology is available today and its unique features could give a boost to a number of new applications. It can also greatly improve user experience for existing applications, especially in a mobile unit. BGPS could be a substitute for AGPS in almost every application, because it has all but one of its advantages and none of its disadvantages. The only advantage left for AGPS is frequency assistance to constrain front-end clock drift to enable longer integration periods for indoor positioning. However this feature becomes more and more obsolete as better and better clocks for mobile devices become available.

Tomorrow, when each end-user device has Internet capabilities, this technology can set the ground for new principles of positioning with GNSS. A user could, in theory, completely abandon use of broadcast navigation messages and use data-free pilot signals, not only to speed up acquisition, but for positioning itself.

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Manufacturers

The iPRx receiver has been developed by **iP-Solutions**, Tokyo, Japan (*www.ip-solutions.jp*). The iPRx front end uses a module manufactured by **Rakon Ltd.**, Auckland, New Zealand (*www.rakon.com*).

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