

Safety Applications for GPS Systems in the Mining Industry

Introduction

The Global Positioning System (GPS) has been available for civilian use for more than 20 years now. It has found many navigation, surveying, tracking and recreational uses. The technology is mature and GPS hardware has become reliable and widely available from diverse suppliers.

How It Works

The US NAVSTAR system has about 28 GPS satellites in orbit. The number varies slightly as old ones are retired and new ones launched. Each satellite carries a highly accurate Caesium atomic clock. The satellites put out a coded time and position signal. A ground receiver with a similar atomic clock can compute the travel time of the signal and hence the range to the satellite.

Theoretically sighting three satellites should be sufficient to determine the position of any point on the globe by trilateration.

However it is impractical to include an atomic clock of sufficient precision with the ground receivers. This problem can be overcome by sighting four satellites. Precise time can then be calculated as the fourth unknown, along with the position co-ordinates.

Accuracy.

In theory it should be possible to use the coded signal to determine position to within 300 mm. In practice variations in the travel time of the signal due to atmospheric conditions and other factors limit the accuracy of stand alone GPS units to 10 to 25 metres.

It is possible to improve on this level of accuracy by utilising a reference station, whose position is precisely known, to broadcast correction signals. The roving GPS unit can then use this signal to correct its calculated position. This arrangement is known as Differential or DGPS.

There are a number of commercial and free to air correction services in use. The Australian Maritime Safety Authority (AMSA), for example, covers about 60% of the Australian coast with DGPS signals.

AMSA specifies the accuracy of their network as better than 10 metres, 95% of the time. Accuracy falls off with distance from the reference station, but our experience indicates that sub metre accuracy is possible within a 50 kilometres radius.

Still higher precision it is possible by moving to a method called Real Time Kinematic or RTK.

RTK systems measure the carrier phase of the satellite signal as well as the code phase. In addition dual frequency receivers can measure two separate frequency signals from each satellite, which enables them to correct for a number of different errors.

Typically RTK reference stations need to be closer to the roving GPS receivers. A minesite will generally need to have its own reference station. All of this adds to the cost and complexity of RTK systems. RTK receivers are anyway more expensive than stand alone or DGPS receivers.

In theory RTK systems could be capable of millimetre accuracy. In practice, current best technology achieves accuracies of about 25millimetres. However this is still good enough to be of interest for surveying and machine control applications.

Surveying

Most mines now use RTK GPS systems for surveying. GPS considerably speeds up the surveying process and reduces the time surveyors are in the field often in vulnerable locations. For example, because the GPS system gives an absolute position, the tedious process of establishing field control points is entirely eliminated.

Truck Fleet Management

Many mines are fitting GPS systems to their trucks for fleet management purposes. Trucks can be assigned to different loading machines in real time to improve overall efficiency. A side safety benefit is that the central control station knows at all times the whereabouts of each truck in the fleet. Stand alone GPS is generally adequate for this task.

High Precision Machine Control

Many mines have started to fit high precision guidance systems to their mining equipment. The systems are accurate enough to eliminate the need for survey design

pegs in the field. Besides greatly increasing efficiency, this eliminates the need to have people on the ground outside vehicles, where they are most vulnerable to accidents.

Dozers for example can complete earthworks, such as dams or drainage channels with no field pegging. Not only do the surveyors not have to put the pegs in, but the operators do not have to climb out of their cabs to look at them. Moreover the machines record the positions that they have worked and so build a gridfile of the completed job. This can be turned into an “as-built” drawing – all without ever having a surveyor in the field.

A further safety benefit of the GPS system was recently revealed when a dozer was involved in a rollover accident. The sequence of events leading to the accident could be thoroughly reviewed because the GPS system had recorded the position of the dozer every few seconds.

Blast hole drills can be set up to complete the blast pattern without the need for surveyors, or the drillers to mark out each hole – again eliminating the need for people to work in the open.

On shovels and excavators, GPS systems can be set up to indicate the exact location of the bucket in three dimensions relative to the boundaries of the orebody or coal seam. In situations where the ore is not readily distinguishable from waste, this can save considerable field time for geologists and surveyors in marking out the ore body limits. Similarly in coal, the ability to selectively mine bands of different qualities is greatly enhanced, again without the need for people on the ground.



Figure 1 GPS systems such as this APS installation on an excavator at Century Mine can largely eliminate the need for people on the ground.

Hazard Avoidance.

GPS systems can be set up to warn the operator of site hazards. For example a hazard warning system has been set up as a trial on a dozer at the Gladstone Port Authority. The dozer is working on a coal stockpile as shown in the photograph in figure 2. Coal from this stockpile is reclaimed through feeders under the stockpile. The dozers push the coal into the feeders. Sometimes the coal bridges, creating a void above the feeder. If the dozer ventures onto the void it will collapse and potentially cause a very serious accident. The GPS system warns the operator when he is getting close to the feeder position. This is often hard to see when the stockpile is full of coal.



Figure 2 - Dozer at Gladstone Port Authority coal stockpile fitted with GPS warning device from APS.

The dozer is fitted with a cab computer which shows the dozer in its true position on a map of the site. It is also fitted with a light bar. More lights progressively come on as the dozer approaches the hopper position. At one metre a warning sounds.

For the accuracy required for this system DGPS is quite adequate – offering substantial savings over an RTK system.

Currently the system is set to warn of the approach to the hopper position in two dimensions. However the GPS system is reading the position of the dozer in three dimensions, and it would be quite possible to allow for the angle of repose of the coal.

It is also possible to set up the dozer so that it automatically broadcasts an assistance required signal at the operators command or if it is tilted beyond a preset angle. The signal from the machine can include its position, making it easy to find.

A similar situation of hazardous openings is encountered in many open pits where the deposit has been previously mined by underground methods. The situation at a gold mine in Western Australia is shown in figure 3. The numerous voids present a severe hazard to mining equipment and vehicles. Most dangerous are the unseen workings just below the current bench level. If the positions of these workings are known, then a GPS system is one way that individual items of equipment could be kept away from the hazard zones.



Figure 3 Voids from old workings at a West Australian Gold Mine.

Collision Avoidance

Another possible use of GPS to enhance safety is in collision avoidance. If all mobile vehicles are fitted with GPS and telemetry systems, they can continuously report their position to a central control base. Software at the base can then analyse the data and warn when two vehicles are on a collision course, as is done with civilian air flights in crowded air corridors.

Such a system is possible, but requires high bandwidth telemetry systems to poll all rovers on a rapid basis. This kind of arrangement would be especially beneficial in areas where light vehicles and high speed long distance ore haulers are mixed.

Reliability

The GPS system has been in place for a long period of time and has come to be relied on for many commercial purposes. On May 1st 2000, President Clinton removed the intentional degradation of GPS signals known as Selective Availability. A repeated theme of Presidential decrees on GPS has been to "encourage acceptance and integration of GPS into peaceful civil, commercial and scientific applications worldwide; and to encourage private sector investment in and use of U.S. GPS technologies and services." It is unlikely that the US will re-impose Selective Availability or otherwise disrupt the GPS system. The use of reference stations in either DGPS or RTK effectively negates the effects of Selective Availability.

Number of Satellites

There is one problem in using GPS in mine site situations, which has become increasingly obvious over the last 12 months. As explained earlier, four satellites are necessary in order to obtain a fix in three dimensions. For high precision RTK operation five satellites are necessary. With the current constellation of 28 GPS satellites, there are rare occasions when only three are visible and almost daily occurrences of only four visible GPS satellites. This applies to a receiver on a flat plain which has an unobstructed view of the full sky.. In a pit where part of the sky is obscured by the pit walls, satellite availability may prevent 24 hour continuous coverage.

There are four potential means of overcoming this shortcoming:

1. Planning. It is quite easy to predict the periods of low satellite availability or when particular areas in the pit will be blocked from sufficient satellites. Using this information, activities can be scheduled around the down times. This is quite practical for surveying applications, less satisfactory for machine guidance and not at all acceptable for safety applications.
2. Other Satellites. As well as the US NAVSTAR system, the Russians have a GPS navigation system too – known as GLONASS. GLONASS was originally launched in the early 1980s for the military forces of the USSR. It has had mixed fortunes over the years, but the Russians are now actively funding it.

GLONASS currently has only nine active satellites, but more are being launched and the system is planned to reach its full constellation of 24 satellites in 2005. Some GPS receivers can access both sets of satellites, giving a total constellation of thirty seven. Dual access, while not guaranteeing 100% availability goes a long way towards it. The chart in figure 4 shows how the GLONASS satellites fill in the gaps left by the NAVSTAR satellites. The European Space Agency is also planning a GPS network – to be known as Galileo. The Galileo system will have a similar number of satellites to Navstar and is planned to be operational in 2008. It is not yet known whether the Europeans will levy a charge for the use of their system. Receivers capable of seeing the 72 satellites from all three systems would be continuously available for high precision positioning in all but the deepest and most steep sided of pits.

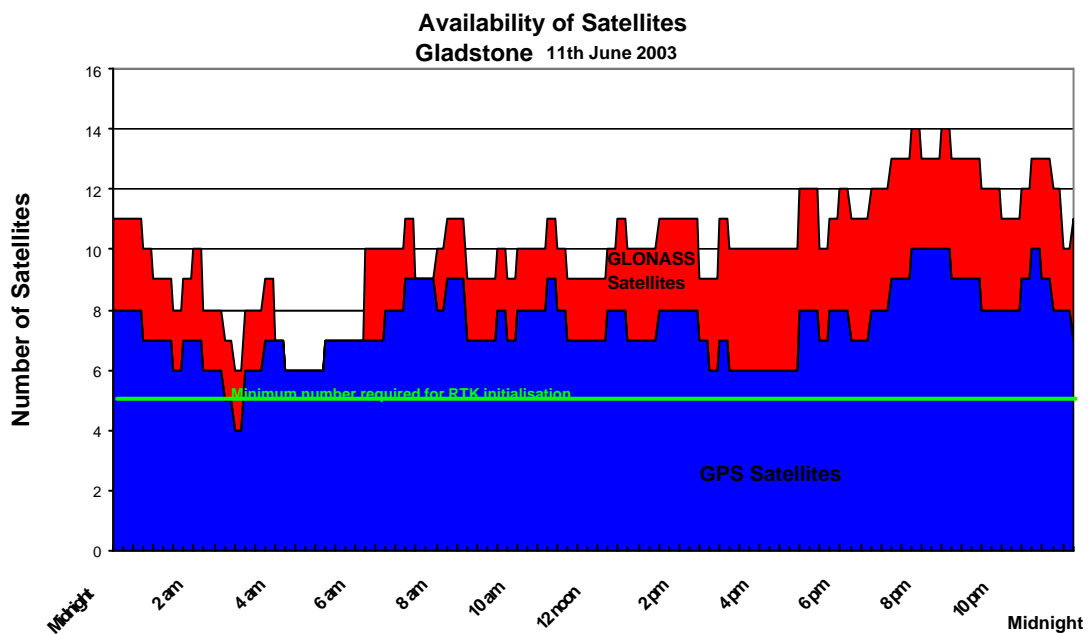


Figure 3 Availability of satellites over a 24 hour period.

3. Inertial. In theory inertial guidance packages should be capable of retaining positions between sighting of GPS satellites. Inertial packages have been well proven in highwall mining applications. In these applications they have been able to maintain design pillars between entries to accuracies of a few

centimetres over 500 metres. However current systems are too expensive and their ability to hold a position is too limited for application in most surface mining equipment.

4. Pseudolites. A number of groups are working on artificial satellites or “Pseudolites”, which would be placed on the pit walls. For various technical reasons, including the swamping of the weak satellite signals by the close pseudolite signal, none are yet commercial. However this technology has great application for the future.

Conclusion

GPS survey and machine guidance applications are finding increasing acceptance in the mining industry. Widespread adoption of this technology has important safety benefits as a by product. In addition there are a number of applications where GPS systems may be fitted for primary safety purposes. Lack of satellites is the major problem to be overcome, but there are a number of possible solutions and more will be available in the future.