GPS, as 2004 approaches — Where To, from Here?

It hardly seems possible that only four years have passed since we announced the arrival of GPS on the earthmoving scene—the demonstration of SiteVision at Queensland's LOGOV Expo in September 1999.

At times we wondered whether our close attention to this topic was becoming a boring fixation to some of our readers, but looking around at today's widespread use of machine guidance, we seem to have been justified in taking the view that GPS heralded a true revolution in productivity.

To mark that 4th anniversary, we've reprinting our original report.

Many of the comments have proved to be colossal understatements. GPS is now in use on all the big projects, and is rapidly filtering down to the smaller jobs.

In this review we bring you two stories of GPS at work in the field—but first, some thoughts concerning the directions machine guidance and control might take in the future. PK

INS — Appears the Most Promising

Twenty four years ago this November, a DC10 airliner of the Air New Zealand fleet disintegrated on the slopes of Mt. Erebus in Antarctica, with the loss of 257 sight-seeing passengers and crew.

Air New Zealand promptly placed the blame on pilot error. The captain's briefing notes were seen in the snow, but mysteriously disappeared from the wreckage littering the crash site, never to be seen again. Vital documents at Air New Zealand's Auckland headquarters were lost into a shredding machine.

In due course a memorably courageous human being, Justice Peter Mahon, was appointed to head a Royal Commission enquiring into the disaster. His investigations became a saga worthy of Sherlock Holmes. In the process he enraged the NZ Prime Minister, Piggy Muldoon, and the Civil Aviation authorities, ultimately wrecking his own career and hastening his death.

I followed the case closely, because firstly I had a very close cobber whose wife was killed in the crash, and secondly I was a pilot.

Supreme Court Justice Mahon got to the bottom of things, and in a report that described the sworn evidence of Air New Zealand's senior management and government officials as "an orchestrated litany of lies", exposed an extraordinary cover-up. Air New Zealand had, in fact, fed the wrong coordinates into the aircraft's navigation system.

In his enquiry, Justice Mahon devoted considerable time and energy to investigating the technology of Inertial Navigation Systems (INS), which have for forty years or more been widely used in aircraft.

The Accuracy of Inertial Navigation Systems

His object was to establish the accuracy of INS, or more to the point, whether there were such inaccuracies as to allow an aircraft, after a five-hour flight, to stray off course so far as to put it in the path of a volcano.

The INS on the DC10 utilised three gyros, recording their displacement in the X, Y, and Z-axes as they travelled away from an initial known point. A computer monitored each gyro and constantly selected an average value from what it determined were the two most accurate gyros of the three. Bottom line—cart the thing all over the place and it always knew exactly where it was, north or south, up or down, in relation to its starting point.

Justice Mahon related how a Jumbo, at the start of a trans-Pacific flight, would park its nosewheel over a paint mark at, say, Gate 14 at Sydney Airport, for the purpose of entering latitude and longitude of that precise known point into the INS. It was common that when the aircraft approached Los Angeles at the end of the flight, its position was accurate within a matter of hundreds of metres.

So What's the Point?

What has all of this to do with earthmoving machine guidance, twenty-four years later?

That answer will have to come in due course from Steve Berglund and his team at Trimble. Like the man who "liked the product, so he bought the company", Trimble recently announced that it has purchased Applanix of Canada, an INS specialist that "develops, manufactures, sells and supports precision products that accurately and robustly measure the position and orientation of vehicles in dynamic environments."

Problem of "Losing" Satellites

Clearly Trimble are addressing the problem with current GPS systems that occurs when the receiver loses sight of satellites, perhaps when a machine moves into the shadow of trees or tall buildings. From the standpoint of reliable performance for earthmoving contractors, this is an issue that won't go away.

When such a dropout occurs, the GPS obviously knew precisely where it was just before it lost its grip on the satellites. So a possible solution is that INS, perhaps as an optional plug-in where adverse conditions warranted it, would allow the system to carry that positional certitude forward until the GPS receiver re-acquired sufficient satellites.

Or—Is this Industry About to be Stood on its Head?

A somewhat more radical approach would be to abandon "GPS right or wrong" and adopt the same philosophy as the aviation industry, where navigation continues to rely on an

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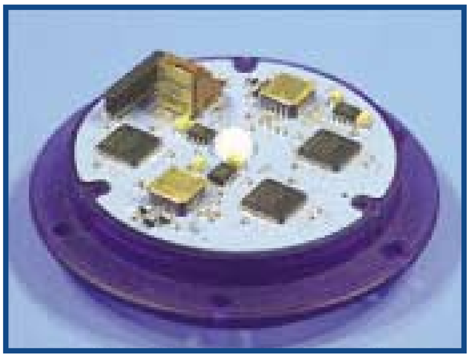

Special Feature – GPS: Where To, from Here?

Left: latest MEMS-IMU, the size of fifty cents.

inertial reference system, and GPS is relegated (so to speak) to the role of simply providing correctional input. The aviation industry has never accepted GPS as a sole means of navigation.

This is not tossing out the baby with the bath water. Much of what has been achieved in machine control and guidance has nothing to do with GPS. The display in the cab that relates the machine to the on-board design doesn't care where the positional information comes from—indeed, most of today's systems can use laser as an alternative to GPS.

Positional data from INS would be equally acceptable. Indeed, it would be *better* because of higher data rates and the ability to deliver orientation data, which is currently obtained using vulnerable external sensors.

'Inertial' technology, like everything else, has come a long way since Mt. Erebus — you would expect that, because it is at the heart of navigating every craft on a space mission. NASA has been behind some impressive recent advances, chasing reliability for unmanned voyages that might last fifteen, twenty, fifty years.

The old mechanical gyros that worked on the same principle as a mid-century child's top have retreated together into history. Hemispherical resonator gyros, laser ring gyros, and microelectromechanical system (MEMS) gyros, amongst other exotic-sounding devices, have been competing for primacy. They all do the same job; they are Inertia Measuring Units or IMUs. We're told that the MEMS-IMU shows the most promise—its full name is, ahem, a "microelectro-mechanical system—inertial measurement unit."

In referring to a box that could talk to the computer on board an earthmoving machine, it's probably more technically correct to refer to a "positioning and orientation device using MEMS-IMU technology". But since that's too much of a mouthful, we'll stick to the older term, "INS"—Inertial Navigation System.

From being bulky, very expensive, and somewhat fragile, the new generation of IMUs now offers solid-state reliability, terrific robustness (capable of withstanding 25,000 G's), and greatly reduced cost—at a size little bigger than a fifty cent piece.

The U.S. Army has its eye on these for tanks, doubtless anticipating that they may cop a few high-explosive shells. So their ability to survive in the earthmoving environment is beyond question.

It may take a few years, but it's our view that the way forward will involve a major shift towards INS.

–Peter Kerville

VRS — At Risk of Missing the Bus?

A VRS network is a way forward in the sense that its capable of disseminating very precise correctional data over a very large area.

It does away with the need to have a locally-established base station in the vicinity of the earthmoving operations.

Base stations are expensive, and out in the field they are vulnerable to damage and theft. If a site is large, more than one may be needed, or a base station may inconveniently need to be shifted.

VRS uses a network of existing permanent base stations, together with software that puts their positional data into one big pot. You phone in, and the system sends you correctional data from an imaginary, or 'virtual', base station that the VRS computer creates to suit your localised needs.

Australia's first commercial VRS network has been established by the Queensland Department of Natural Resources & Mines. It utilises GPS assets previously established for other purposes on the Department's buildings in Brisbane, Ipswich, Bundall and elsewhere, giving the network a coverage extending from Noosa to the NSW border, and well out west of Brisbane. This is potentially a very powerful tool.

(If you'd like more technical detail, it's available in a couple of earlier stories we've published, at www.kerville.com/gps).

It shouldn't really be described as a shortcoming, but the fact is that this VRS network utilises the mobile phone system for data transmission. That is, your GPS receiver is linked to a mobile phone that calls in its approximate position, and receives its corrected position.

For surveyors getting around with rovers, wanting to take a few shots here and there, this is an acceptable approach. But for machine-born systems needing a constant stream of data, it's not cost effective.

Matt Higgins of the DNR&M tells us that they've undertaken trials, transmitting data via a landline and modem, then onwards from a base station by radio.

Unfortunately, rental of the land line from Telstra is expensive, and contractors tell us that the DNR&M component is fairly stiff, too.

In practice, the Queensland VRS network has so far failed to capture the interest of earthmoving contractors. That situation won't change until a method of distributing data is readily available that economically satisfies their needs. PK

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Part 3 of our Special Feature on possible future directions for GPS technolgy–

What the Heck are Pseudolites?

Now this is wildly futuristic, so don't take too much notice of it—yet.

What an extraordinary thing it would be if, looking back in ten years, the pursuit of GPS accuracy had been leading us up a dry gully. It would be comparable to (for example) a major breakthrough being made next week that allowed engines to run on water. One hundred years of investment in fossil fuel powered internal combustion engines rendered irrelevant. Don't laugh—it happened to steam engines.

Taking the broadest possible overview of GPS, what happened was that the American and Russian military establishments launched constellations of satellites for their own destructive reasons, and commercial entities discovered that they could harness 'free' signals to solve positioning problems.

This is an approach that's very valid when applied over large and remote areas of the earth's surface, for the guidance of munitions, aircraft and ships.

But is it the best possible solution where the application is in a smaller area, only a few kilometres across, needing millimetre accuracy? GPS, after all, stands for Global Positioning System, with the emphasis on Global.

Is it essential that the signals come from satellites?

The term 'pseudolite' (pseudo-satellite) describes, as the name implies, a ground-based transmitter operating on GPS frequencies that pretends to be a satellite.

Pseudolites have the potential to fill in gaps in reception in difficult terrain—hilly, or shadowed by trees or large buildings. And they have the advantage of being stationary, at a precisely known fixed spot.

Research conducted in Australia, where pseudolites were installed on tall buildings to augment satellite signals, has shown promise. It also revealed some problems, not insurmountable.

But pseudolite technology is not viable as it stands at present. It can't just be 'plugged in' to existing solutions. Amongst the problems are these — their signals overpower conventional GPS receivers and the radio spectrum is not legally available for their use. There's also an industry perception that pseudolites are too expensive to be a viable alternative to satellites, but we're told that that's far from being the case.

To harness them what's needed is a specialised receiver that's capable of handling both satellite and pseudolite signals, the latter operating in a different spectrum.

The fact is, satellite signals arriving on earth are feeble, and to a minor degree, unreliable. But signals from nearby transmitters, as we all know, are not shadowed by trees and buildings. So, a group of pseudolites erected at suitable vantage points around a site might well supply advantages over satellites, whilst employing the same basic technological approach.

Australians are pushing ahead strongly in this field, perhaps more strongly than others, and we'll soon report on their efforts. Watch this space! PK