A picture of the future of radionavigation

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Tokyo, Japan, 25 October 2004

Abstract

This paper presents a snapshot of the current state of the world of radionavigation and speculates on its likely future development. It notes that in Japan the view of radionavigation is focused on users and markets and not, as is the case in Europe and the US, on aviation and maritime systems and navigators. It reviews possible reasons for breaking away from sole dependence on GPS. It argues that both the attempt to achieve independence of GPS, and the wish to make money from operating satellite systems – both key drivers of the development of Europe's Galileo – are misguided. On the other hand, the desire to have more satellites is well-founded, provided they are compatible with GPS. Both global satellite systems such as Galileo, and regional ones like Japan's QZSS, will bring higher availability and continuity. Together with augmentations, they will also enhance accuracy and integrity. However, only a terrestrial system is likely to offer protection from the threat to satellite navigation offered by interference and jamming. The paper reviews the messages of the US Volpe Report, notably the suggestion that Loran-C has a role to play. It shows how Loran could fit into the future radionavigation mix, alongside satellite systems, their augmentations, and the great unknown factor: our future indoor location technology.

A different view of radionavigation

We live in a world, and we are meeting in a country, in which radionavigation means satellite systems, and satellite systems chiefly mean GPS. Japan was one of the first countries to see the potential of GPS, pushing ahead rapidly with a range of consumer products. Eventually Japan established the largest GPS user base in the world plus a substantial manufacturing industry for satellite navigation equipment (Slide 2).

GPS sales in Japan are far out of proportion to the size of the country or its economy. Two million car navigators are sold in Japan each year, there are10 million of them out there, and 60% of the population have cell-phones, with many now being GPS-equipped. It is interesting to observe that whenever the future of radionavigation is reviewed in Europe or the US people look immediately at the various modes of transportation (Slide 3), maritime or aviation, and only then at land navigation. The viewpoint is that of a government, a provider of services, and rarely that of a user. The view from Japan is different (Slide 4). Here you speak of users and equipment manufacturers; you think of markets; your focus is on consumers. Of course, Japan has important aviation and maritime GPS systems. But people in Japan recognise that these are now small, specialised, parts of a market that is dominated by car navigators and cell-phones and games.

Why use anything other than GPS?

To the general public, location technology and GPS are one and the same thing! Even among navigation professionals, GPS is the reference point, the gold standard. Considering the future of radionavigation, most people would ask: why on earth use anything else (Slide 5)? Why set up another satellite system, never mind a terrestrial one. That is the key question in the planning of radionavigation systems. It lies at the heart of the present European Navigation Plan study, of the US Federal Radionavigation Plan, and of national plans across the globe. It is also a central issue for this International Loran Association whose raison d'être is to promote a radionavigation system very different from GPS. Well, as we have heard this afternoon, there are good reasons to consider alternatives to GPS, some political, some commercial, some technical.

Independent ownership? A powerful argument for an alternative satellite system, one that drives the development of Galileo in Europe, is ownership, independent control of the system. Nations see GPS as a public utility. Losing it would damage their industry, commerce, and telecommunications. And yet control of this vital part of their national infrastructure lies in the hands of another nation. They worry that US policy (Slide 7) is to "limit availability of" its "radionavigation systems in the event of a real or potential threat of war, or impairment to" US "national security". As recent events have shown, other nations may disagree strongly with the US about national security.

But how far should ownership should we go? Should Europe have its own system? Should the UK? Should my home village of Llanfairfechan in Wales? For most nations, ownership is simply not an option. And in any case, can we truly be independent of GPS? The US has told Europe clearly that if Europe operates Galileo in a theatre of conflict from which the US has withdrawn GPS, the US will jam Galileo. So, there is no independence there! And Europe is coming to recognise too that there is very little market for an independent Galileo with separate receivers, especially not for the paid-for services that Europe plans. So, the US and the European Union have now agreed to use the same codes and frequencies. Low-cost receivers will pick up both GPS and Galileo. Users will not know that there are two separate systems, or care (Slide 8). Galileo, and Japan's QZSS too, will cooperate with GPS, not compete. I suggest: independence in satellite navigation is a myth!

A chance to make money? Another driver for Galileo is Europe's wish to share the economic benefits of satellite navigation. The US has told the world that GPS is an "integral component of the Global Information Infrastructure", with a myriad applications (Slide 10). It has said that operating GPS has "generated a huge US commercial … industry" (Slide 11). So, other nations want their share of the cake and reckon that they too should run satellite systems. Are they right to think that way?

Well, remember Slide 2? Japan has shown us all that you do not need to own, or operate, the satellite system in order to make money from satellite navigation. For every satellite up there, there are a million receivers down here, plus a host of associated communications and display systems. No, the money is made on earth! So, "sharing the rewards" by running your own satellites may well be another myth.

We need more satellites! Others say that we need more satellites, that buildings block the satellite signals in cities and so limit many applications. This is true. If you cannot see enough satellites, you have no satellite navigation. And having just enough satellites gives poor accuracy. There is no doubt that having more satellites increases the availability of satellite navigation. Galileo will add some 30 satellites to the 30 of GPS: that will mean 60 satellites for Europe. But it will also mean 60 for the US, and for Japan, too.

Japan's proposed Quasi-Zenith Satellite System (Slide 14) will add even more satellites. But they will serve just this region, not the whole world, like Galileo. That makes good economic sense; especially since these QZSS satellites will also enhance the augmentation system and mobile communications.

Higher accuracy and integrity? The accuracy of GPS is dominated by uncertainties in the time delays incurred as the satellites' signals as pass through the earth's atmosphere. Augmentations - differential systems - greatly improve accuracy (Slide 16). As well as higher accuracy, WAAS, EGNOS, MSAT, and coastal radio beacons give higher integrity, ensuring that receivers truly are where they say they are. If a satellite goes wrong, these augmentation systems warn the user immediately. Let us be clear, though: augmentations are not radionavigation systems, simply extensions to GPS. Without GPS, augmented GPS would fail.

Vulnerability to interference and jamming? The US government's Volpe Report has spelled out the risks that the US takes if GPS is the US' only means of navigation, and the only source of precise timing for the country's telecommunications systems (Slide 18). The report tells us: that interference to GPS - unintentional or intentional - can be reduced, but never eliminated; that losing GPS would cause severe safety and economic damage to the US; that GPS is a tempting target to individuals, groups, or countries hostile to the US; and that GPS can be jammed, or receivers spoofed into giving hazardous, misleading information. The Volpe Report says that we need backup systems and procedures in critical applications; the US Department of Transportation has worked hard to develop such backups. The message of the Volpe Report is that GPS is vulnerable.

The little jammer in the dice in Slide 19 would kill GPS operation throughout this building. A more powerful jammer would do so across the city of Tokyo, stopping the use of GPS in cell-phones, cars, ships, and aircraft. Jammers could attack Japan's 9000 GPS-synchronised cell-phone sites eventually causing a loss of communications, and possibly the synchronisation of the power grid as well. Who here is equipped, trained, and ready to track down a powerful jammer installed in a car? I suspect: no-one!

In the California harbour shown in Slide 20, a couple of cheap TV antenna units went wrong recently. As a result, GPS stopped working - or give wrong positions - on every vessel in the harbour and for a kilometre out to sea. It took months to track down this accidental interference. There are GPS jammers on the Web (Slide 21). It does not take *Al Qaeda* to block GPS reception, just a bored kid with acne and no girl-friend! GPS is currently as vulnerable as the computer business was before the arrival

of the first virus. I think we will see an increase in jamming as GPS is used for road charging (Slide 22). We certainly need alternative navigation systems to GPS!

Indoor navigation? And then there is the matter of indoor navigation. Imagine a world in which your mobile phone worked well out in the countryside and in suburban areas, but in the city it became intermittent, and indoors it stopped working altogether. That would be unacceptable. But our GPS location services behave like that.

This is currently the great technical battleground, indoor navigation (Slide 24). Some companies are working to push GPS coverage further into buildings, using very sensitive receivers and employing massively-parallel correlators or signal acquisition assistance sent via mobile phones. Others are experimenting with the use of the cellular signals for indoor location. Both approaches work, but are unreliable and inaccurate. Some companies install beacons throughout buildings, often with signals compatible with GPS in an attempt to achieve a seamless location system outdoors and indoors. This works too, but it is very expensive.

Some of us think we should use the WiFi nodes in the building as location devices (Slide 25) and then pass the tracking data straight over the Internet. But, frankly, no-one yet has the solution to indoor navigation. And the answer may turn out to be the use of tiny inertial sensors, and not radionavigation at all. We are all agreed, though: indoors, we certainly need something more than just GPS.

Why use anything other than GPS - Summary

So, here is my assessment of this question of alternatives to GPS (Slide 26):

- Owning the satellites does not give you independence. It is simply not an option for most nations. Its benefits are largely mythical.

- You get most of the financial rewards by selling equipment and operating businesses, not by running satellite systems.

- We certainly need more satellites than GPS will ever provide. Galileo and QZSS will give us higher accuracy and integrity. They are good news, provided they are compatible with GPS so that low-cost receivers can use whatever signals are available.

- Higher accuracy comes from augmentations such as WAAS, Eurofix, or coastal beacons, working in collaboration with the satellite systems. They also enhance integrity.

- GPS is vulnerable to interference and jamming. Galileo will share GPS frequencies and be vulnerable to the same interference. So, we definitely need non-satellite systems.

Aviation systems

What will these non-satellite systems be? In the short term, they will be what we had before GPS came along. Think of aviation, with its NDB, VOR, DME, and ILS. We still use them. They are established, proven, and standardised world-wide. After 26 years of GPS satellite operation, we still do not have a satellite-based landing system with the availability, accuracy, integrity and continuity of the Category 1 Instrument Landing System first demonstrated in 1938! The US Federal Aviation Administration has had to back off from a satellite-only policy, the Local Area Augmentation System is dying, and the huge sums spent on WAAS have made very little impact at the sharp end of aviation. Indeed, new ILSs are currently being installed worldwide. Oh, satellite navigation will win out in aviation in the long term, but do not hold your breath!

Aviation has its well-established radionavigation technologies. What about marine and land users? The US Volpe Report suggested Loran-C (Slide 28). It says that Loran is a viable navigation system for coastal maritime operations, for tracking on land, for telecommunications timing, and that it could possibly form a backup for aviation. In response, the US Department of Transportation set Loran a number of goals: successful aircraft non-precision approach, maritime harbour entrance guidance, and Stratum 1 timing. The expenditure of a lot of US government money resulted in a modernised Loran, Enhanced Loran, or *eLoran*. According to the US Secretary of Transportation, eLoran can meet the goals set and has also demonstrated cost-benefits.

The role of enhanced Loran-C

Let us assess eLoran against the criteria we used earlier (Slide 29):

- Ownership: Each nation or region runs its own Loran.
- Share of rewards: Anyone can develop and sell the equipment.
- More satellites: There are of course no “satellites”, but Loran stations’ signals are markedly more available than satellite signals, in the areas where both are available. The Loran signals penetrate forests, urban canyons, and even some underground car-parks.
- Accuracy and integrity: Where Loran Additional Secondary Factor data is used properly, the accuracy of eLoran is comparable to that of GPS, and eLoran also has built-in integrity checking, which GPS does not.
- Vulnerability: Loran is less vulnerable to interference and jamming than GPS. Roughly 10,000 times higher signal power reaches a Loran receiver than a GPS receiver. So a Loran jammer needs to radiate a lot more power than a GPS jammer, and that at a frequency at which radiating power is harder.
- And indoors? Well, Loran can be better than GPS, but frankly, neither Loran nor GPS is the answer to indoor navigation.

Why not Loran-C *in combination* with GPS; that arrangement gives the best availability, continuity, accuracy and integrity of all.

The future radionavigation mix

So, it seems to me that the future of radionavigation will shape up like this (Slide 30):

- GPS in its present version, or in future versions if and when they arrive.

- Other satellite systems, probably Galileo globally, systems like QZSS locally, all compatible with GPS so that receivers can use whatever signals are available. All will be free-to-air at the basic level, with additional paid-for services for specialised users, plus military services.

- Wide-area augmentations (WAAS, EGNOS, and MSAS), plus local area augmentations (maritime radiobeacons and Eurofix). Again, these will be free-to-air. In addition, there will continue to be many specialised services.

- Traditional aviation aids to navigation will continue to be employed in the short and medium term. These will certainly include ILS and DME, although there will be fewer NDBs and VORs than at present.

- Enhanced Loran-C for maritime and land use, with some aviation use. There will be combined satellite-Loran receivers, with the two systems so well-integrated that many users will neither know nor care which system is providing their navigation service.

- And finally, indoor navigation? No technology has yet emerged as the clear leader. But there will be one to add to our list!

So, radionavigation at its frontiers continues to be as demanding as ever, as exciting, as difficult to predict. And, it goes on being a success. We do not often pause in our rush forwards and our rivalry between systems, to consider this: radionavigation, especially satellite navigation, has been a star among science-based industries. It has delivered huge growth, with products ever more powerful, more user-friendly, and more cost-effective. And, unlike almost every other high-tech industry, people love us: we help blind folk find their way and look after little children! Radionavigation does not pollute the atmosphere, and it does not frighten the horses. We are good news! We can move into the future of our industry with enthusiasm and confidence.

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