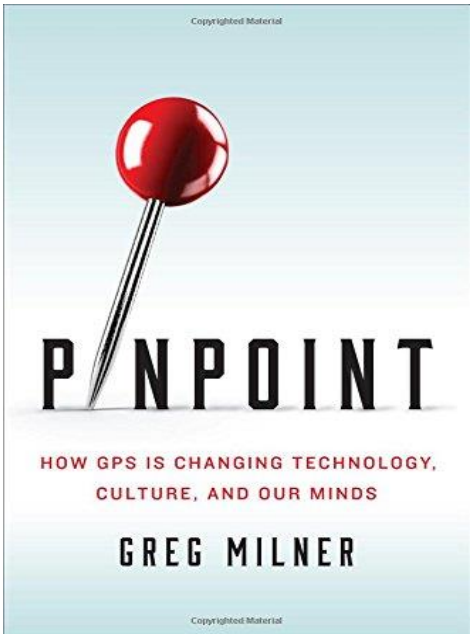
Greg Milner

Pinpoint: How GPS is Changing Our World

(Granta 2016)

Dick Pountain
dick@dickpountain.co.uk



We often talk about science and technology using some notion of the extension of human senses and powers, through instruments and machines that we, rather than nature, have invented. Some obvious examples: the telescope extends human vision, enabling our eyes to see things further away; the microscope extends our vision in the opposite direction, to the very small, the amoeba and bacteria, eventually even to atoms themselves; the internal combustion engine amplifies our muscle power, to lift heavy weights with a forklift or travel at 200 mph in a Formula 1 car. Some of our machines provide us with wholly new senses, as X-rays and NMR scans let us see through opaque matter or television lets us be present at remote events.

Unlike some other animals, for example migrating birds, human beings don't possess a built-in sense of absolute location on the surface of the planet, which tempts me to describe the Global Positioning System (GPS), subject of Greg Milner's excellent book *Pinpoint*, as the provision of this new sense. However, that isn't really what's going on here at all, because GPS doesn't give people extra powers in the same way that peering into a microscope does. Instead what GPS does is enhance the world itself, in such a way that we can then invent devices that tell us where we are.

Nature only provided us with one planet and one moon, but the US military establishment – for entirely pragmatic reasons to do with fighting wars – decided to create 31 extra artificial moons, which orbit at a distance of 20,000 kilometres, far closer to us than the natural one, and which continually transmit the time of day by means of extremely weak radio signals. These satellites cover the whole planet, and are accessible by anybody, which makes them the first truly global utility. They're paid for by the US Treasury and provided to the world for free. And they are totally passive, in the sense that they do nothing directly to you or for you. If, however, you choose to detect those extremely weak radio signals, they can tell you exactly where you are, to within a few millimetres, in much the same way that the earth's

natural magnetic field has for centuries enabled seamen to know which direction is North by using a compass.

GPS enhances the planet itself rather than our own senses, in the same way that irrigation canals and ploughed fields once enhanced it, and just like those more ancient technologies this enhancement does not remain permanent without constant maintenance and huge expenditure of effort. Greg Milner's' book provides a well-informed and gripping account of what this effort involves, how the decision to fund it came about, and how it works, in language that's accessible to non-technical readers.

The idea for GPS emerged in the early 1970s, among US Airforce personnel who were disgusted with the air force's policy of carpet-bombing during the Vietnam War. They regarded this strategy as both inhumane and ineffective, an obsolete relic of World War 2 thinking, which not only caused massive civilian casualties, but also cost aircrews' lives, since its inability to hit important targets reliably meant frequent return missions. In 1973 Brad Parkinson, prime mover of a group of Pentagon scientists, proposed the creation of a satellite navigation system that would enable precision targeting, with this pithy statement:

> *The mission of this Program Office is to*
>
> *- Drop 5 bombs in the same hole*
> *- and build a cheap set that navigates*
> *- and don't you forget it*

Milner tackles the byzantine departmental politics, inter-force rivalries, competing programs and funding struggles that preceded the go-ahead for the launch of the GPS satellites with great panache, making this the most gripping technical book I can remember since Tracy Kidder's 1981 "Soul of a New Machine". He doesn't skip over the technical issues, but summarises them with great skill.

GPS happened when it did thanks to a convergence of three technologies. Rocket and satellite science had received a great boost in 1957 thanks to the panic over the Soviet success with Sputnik. Atomic clocks based on the frequency of transitions in caesium 133 atoms were invented in 1955, permitting time-keeping of unprecedented precision, but it was only in 1964 that Hewlett Packard made one small enough to be mobile. Put together, these two technologies were enough to create the network of GPS satellites and that feeble radio time signal, but a third leg was required, a receiver small enough, cheap enough and powerful enough to use the differences in the time signals from several satellites to calculate the receiver's position on earth.

At first such receivers were huge, expensive, and confined to military users. The military attempted to restrict the accuracy of GPS to preserve an advantage – another story that Milner tells very well – by providing two signals, one secret and a less accurate public one. What happened next was the microprocessor revolution, which lead first to the personal computer and eventually to the smartphone. As Moore's Law became unstoppable, electronic components shrank and computing power burgeoned at an exponential rate – any

attempt to monopolise the accuracy of GPS positioning was doomed by the ingenuity of electronic inventors, who found ways to extract even more precision from the public signal than the military had.

As GPS found more and more users outside of bomb-dropping, commercial pressures demanded a series of enhancements that transformed its performance to the almost miraculous. The airline industry needed sufficient accuracy to guide landings in zero visibility, which meant increasing the precision of GPS from 99.99999% to 99.9999999%. Though the maintenance, orbit adjustment and software-updating of the GPS satellites remain matters of US national security and are still performed from Schriever Airforce Base in Colorado, innovations are now contributed from universities, commercial firms and government departments all over the world.

According to Milner “You and I use GPS to know where we are, but the world uses it to regulate time. First and foremost, GPS is a clock. As a timekeeper, GPS is impeccable – always available, always accurate, always free.” The world’s standards laboratories now all synchronise with one another via GPS. All telephone systems, both landline and mobile, employ GPS timing to keep digital signals in strict lockstep as they traverse worldwide networks. The same is true of electricity and water companies who employ GPS timing to monitor demand in real-time across their networks and so avoid local overloads. The financial service industry is now dominated by high-speed trading in which shares and currencies are bought and sold automatically within nanoseconds of any price change, all under the control of GPS timing.

It is somewhat surprising that GPS is used most for timekeeping alone, but its use for geographical location has grown to be of immense economic importance too. Milner devotes a chapter to the US sugar beet industry, centred around vast agribusiness farms in the Mid-West, which pioneered the use of GPS to plant crops. Every tractor is equipped with a state-of-the-art GPS receiver and is connected by radio to a computer database of terrain and soil fertility data, so that the exact quantity of beet seed and fertiliser is automatically planted, to the optimum depth according to soil conditions, over every centimetre of each field. Hundreds of years ago a farmer with an ox and a wooden plough knew every inch of his own field, and developed a similar intuition of how to plant. Tractors caused this intimate knowledge to be lost during the 20th century, but GPS brings it back in cyborg form. Milner estimates its effect on yields is worth $33 billion a year.

Another huge application of GPS is in the transport industry, where it is used to organise fleets and monitor delivery journeys. This has caused resistance from drivers who resent being spied on, and Milner does not try to avoid this issue, in part because it led to the illegal sale of GPS jamming devices, a topic which leads into a chapter on security and the spoofing of the GPS signals. We now depend so much on GPS that disruption by terrorists or during a war becomes a matter of grave importance.

Of course, the largest number of individual users of GPS are those millions (billions?) who employ Google Maps on their smartphone or a TomTom or Garmin in-car satnav to get to where they want to go. In a chastening chapter called ‘Death by GPS’ Milner reports some

examples of the way that over-reliance on satnav has caused drivers to abandon common sense cues, with sometimes fatal results – like driving off an unfinished bridge, or up a precipitous cul-de-sac in Death Valley. Milner uses this chapter to explore several research projects into the effects of GPS on our minds: in particular, on our spatial awareness and cognitive maps of our immediate surroundings.

In 1948 the US psychologist Edward Tolman published research which suggested that human brains construct two different kinds of map of our immediate surroundings: *comprehensive maps* are two-dimensional representations of the terrain, studded with landmarks that we have learned and their relative positions. The alternative *strip maps* are one-dimensional lists of instructions for proceeding from A to a B - route maps. Milner surveys the more recent work of several teams of German, Japanese and US researchers who all concluded more or less the same, that daily GPS use is altering our cognitive mapping abilities, eroding the comprehensive in favour of the strip. We learn fewer landmarks and less context since we can always look it up on the satnav.

In a neat structural flourish, Milner both begins and ends *Pinpoint* with a discussion of the ancient Polynesian navigational art called *etak*, which over centuries enabled their colonisation of the whole of the Pacific Ocean with sailing canoes, without the use of instruments. The art, which took a lifetime of experience and tuition, has now been lost. At a time when Westerners had yet to survey the Pacific completely or accurately, Captain Cook met and employed a Tahitian man named Tupaia, a practitioner of *etak*, and persuaded him to draw a map, which no-one could understand (nor has yet). What is clear is that like a GPS satnav, *etak* is a self-centred system which measures everything from yourself as the fixed point, with the world moving to meet you. It seems to involve learning the position of familiar nearby islands, even ones invisible beyond the horizon, relative to fixed stars in the night sky, and combining this with a host of other cues like currents, winds, patterns of surface ripples, bird flights, even smells.

If the use of GPS really is diminishing our own ability to sense our surroundings, does that threat outweigh its benefits? In the UN's Millennium Development Goals which he helped write, US economist Jeffrey Sachs stressed the importance of GPS-assisted agriculture to raising the productivity of developing nations in a sustainable fashion. Indeed, GPS could stand as a symbol for those goals, as the first truly worldwide utility, belonging not solely to the USA but to 200 nations cooperating for mutual advantage. On the other hand, the same GPS that helps inject the optimum amount of seed and fertiliser into a Colorado beet field also guides the 8 kilos of PBXN explosive in the warhead of a Hellfire missile during a drone strike in Afghanistan. Will Donald Trump's nativist, anti-science administration, and its possible successors, be willing or even able to maintain its availability? Despite the excellence of his book Greg Milner cannot answer these questions, and neither can we, yet.