Forum

Land Navigation

A short account of the Conference on Land Navigation and a list of the papers presented is printed in the Record. The two papers printed below are the President's opening address to the Conference and Captain Maybourn's summing up of the conclusions.

Overcoming the Market and Technology Mismatch

J. E. D. Williams

The title of this address could perhaps more positively be: 'Exploiting the available technologies to satisfy the operational requirement in the best way'. It is a very old and familiar problem in navigation and location. Take position finding at sea before radio, for example. As the Earth is rotating, if you do not know the time you cannot determine, astronomically, your own longitude. So, before the chronometer, sailors took their shots of the Sun at local apparent noon to find latitude, and homed along the parallel of their destination.

When the marine chronometer was invented in the middle of the eighteenth century it would have been obvious to any astronomer who thought about it that the information available at sea from any one celestial observation is a line of position at right angles to the azimuth of the body and that the unique way of calculating the position line without solving more than one spherical triangle is what we now call the intercept method. What happened in fact was that sailors went on as before finding the latitude at noon but using the chronometer with morning or evening sights to find longitude. The position line was discovered generations after the chronometer by a New England sea captain, empirically and almost by accident. The intercept method was eventually developed by a French naval officer in 1875. The operational technology was lagging the potential technology by nearly a century.

The point of my anecdote, and its relevance to this conference, is that it would have been as unreasonable to expect eighteenth-century astronomers to divine what seamen needed (as opposed to what they thought they wanted) as it would be to expect seamen to know what astronomers could devise. In this problem of discovering how best to apply the state of many arts to an operational process we have gone a long way since those days. Particularly since the middle of the second World War there have been two main thrusts. One is improved methods of analysing the real nature of the operational requirement, expressing it in scientific terms and, where appropriate, applying the methods of operational research to the solution.

The other main thrust is improved communication between the operational practitioners and those who profess some discipline which might contribute to a better

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operation. It is in this way that the Royal Institute of Navigation plays such an important role. Its sole objectives are to unite in one body everyone with an interest in navigation, to advance navigation and promote knowledge of it. The Institute achieves its purpose by disseminating new ideas in its journal and by study groups, discussions, lectures and conferences, acting as a forum in which people from different disciplines can contribute to problems of a navigational nature. Hence this conference.

We are all navigators; we must be, since we all arrived here. For the most part, we navigate by processing with our brains the evidence of our senses supplemented, where necessary, by reference to maps and visual signposts. Navigation by instruments has long been perceived to be necessary at sea, in the air and, in the case of land vehicles, in a military context or in journeys over trackless country. In recent years there has been a growing awareness of the possible benefits of applying instrumental navigation techniques to the operation of vehicles which are normally confined to defined roads in well-mapped territory. Developments in navigation and, perhaps more generally, in data processing and communication, have reached a point in which a more sophisticated approach to the navigation and control of land vehicles may be rewarding.

Two main classes of operational requirement may be identified. One is vehicle guidance to a desired destination. Obvious examples are a van driver or a taxi driver trying to find a suburban or rural address which cannot always be easily identified by reference to road maps. Another would be any driver seeking to find his way through the one-way system of an unfamiliar city without stopping the traffic every few minutes to consult a map.

The other main class of requirement, quite different from the guidance problem, is knowledge at some operational control centre of the positions of all the vehicles in a fleet in order to maintain optimum deployment in changing tactical situations. This of course is already done, for example by police forces, mini-cab firms and so on, using reports on position by the driver over two-way radio systems. But there are obvious advantages in automatic vehicle location (AVL) which could provide the location of vehicles either to be displayed continuously or on demand at the control centre. Drivers may be too busy to report, they may not know where they are but only where they are going; the driver may be motivated to give inaccurate information; the vehicle may even be hijacked. Besides, voice reports are all very well if control is heuristic, but AVL expresses position information in a more suitable form for computer input if the location data are to be processed by computer in the course of the control function.

Other possible applications of instrumental navigation can be envisaged but I suspect that most interest will be generated in these two cases: AVL for operational control of the fleet and guidance to a destination for the driver of the vehicle, not necessarily both for the same user.

Instrumental navigation offers three generically different kinds of location systems. One is the electronic signpost which says, in effect, 'you are now here at my position'. An aviation example is the marker beacons of an instrument landing system.

Many interesting suggestions for signposts in an urban environment have been made. Signposts can be inexpensive and accurate. The obvious limitation is that you only know your location when you are at a signpost, but they can be used in conjunction with a dead reckoning (DR) system. Since the accuracy of DR positions deteriorates with the extent of the motion since the last fix, DR systems require updating from time to time, and this might be done by signposts. DR systems vary enormously in price and complexity, from the obvious and cheap compass plus odometer to inertial navigation systems (INS) which are at the heart of the navigation systems of Boeing 747s and nuclear submarines. INS has, in fact, found a military application in land vehicle navigation, but

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in most cases its costs would be prohibitive. Generally, DR systems are not required if fixing is continuously available.

The third genus is fixing systems available over an area, usually on a continuous basis. Dozens of systems have been developed since directional antennae were invented eighty years ago. The cheapest and simplest is to fit a loop aerial to your car radio and sense the direction of your local radio station. Inexpensive computers can convert bearings from two transmitters into a grid reference. However, a loop aerial only gives bearings relative to the direction the vehicle is pointing and some other instrument, such as a compass, is required to give bearings relative to north or some other reference.

Accuracy is very low: for one thing the whole vehicle is an aerial, a radiator and a reflector. For this reason modern systems avoid putting the onus of sensing the direction of reception on equipment in the vehicle. There are two ways of doing this. One is to arrange for the radiation pattern of the signal transmitted to vary in direction, so that the receiver in the vehicle determines the direction of the transmitter by analysis of the signal received. This is the principle of the omni-directional range (VOR) on which airways in North America and Western Europe are based.

One problem with this equipment might be that, as it operates on the very high frequency band, it might not be suitable for location of vehicles in mountainous or urban terrain. Indeed, a lot of systems would be unsuitable for land vehicles for similar reasons. An urban environment is hostile to radiolocation in two respects: there is local electrical interference not under the control of the vehicle, and high buildings block and reflect radio waves at the higher frequencies.

The other way of doing it is to have a chain of transmitters synchronized in some way so that the receiver in the vehicle senses the differences in the time taken for the signal to reach it from different transmitters, either by phase comparison in continuous wave patterns, or by actual time measurement in pulse systems, the so-called hyperbolic systems such as Loran-C, Decca and Omega.

We are at an interesting point in the history of location by radio. Almost all the systems using Earth-based transmitters are technologically mature. In the main they have 30 or 40 years development and improvements behind them. In contrast navigation by satellites is relatively in its infancy. The prospects of eventual accuracy are fantastic. At the Greenwich Observatory one team is bouncing laser pulses off a satellite the size of a dinner plate with an accuracy of about an inch, and using the information to measure, for example, the movement of Sussex relative to other observatories. This is scarcely a navigational problem, but it does give a new meaning to the phrase 'the sky's the limit'. Apart from military navigation satellite programmes there are already a number of commercial applications to use geostationary satellites for navigational purposes. Some of the papers, however, make reservations about the application of satellite navigation systems to land vehicles in urban environments (the frequency problem again).

Nearly all the radiolocation development over the past eighty years has been directed at military, aeronautical, marine or space markets. All these markets can usually afford higher price tags than civil land vehicle users. If one is buying a £50 million aeroplane, one can, and indeed does, spend millions on guidance, flight management, communication and control. The economics of getting the navigation of a nuclear submarine right obviously justifies even higher price tags. The numbers work out rather differently for a police car or a delivery van. Quite the most obvious difficulty in matching the technology to the land vehicle market is in the area of price. Manufacturers must learn to think small. Users must learn how to cut their cloth to suit their purse.

This problem, difficult though it is, need not be insoluble. The requirement of aerospace, for example, is often so demanding that the manufacturers have good, or at least plausible, reasons for the prices they charge, although ability to pay may have something to do with it. Even in the context of marine and air navigation it is remarkable what can be done. There are available for light aircraft ADF, NAVCOMM (VOR plus R/T), DME and area navigation computers, at a small fraction of the prices airlines pay. They do not meet airline standards, of course, but they do the same job. You only have to go to the boat show at Earls Court to see the astonishing array of often quite sophisticated navigation equipment on display at prices the recreational sailor can afford. Again, not quite the gear one would choose to negotiate a supertanker through narrow straits in bad weather, but it works.

One sees every day how cheap high-quality products can be. The error of this watch of mine, and the variability of its error, is smaller than that of any chronometer available when I was a professional navigator. It cost me £3 and I was mortified to see similar ones for sale at a petrol station at £1.95. A couple of pounds more will buy an electronic calculator capable of eight-digit arithmetic with perfect accuracy. To get high technology at low cost there are three basic rules.

(i) Use only technology for which the military, aerospace or some other big spender has already paid all the costs of research and development.

(ii) Do not demand high standards of reliability and quality control. No one wants equipment that does not work, but the extraordinarily high standards demanded in some military and aerospace applications are very, very expensive. The great advantage we have in radiolocation of land vehicles is that safety is not directly involved. If the navigation equipment fails it may be very exasperating but it will not cause the loss of 400 lives, not to mention the £50 million aeroplane.

(iii) The requirement must be fitted to a large market. The length of the production run is critically important to price as the examples of cheap calculators and chronometers illustrate. An extra million copies may cost much less than the first ten thousand. It is not the bits of silicon, metal and insulating material which cost the money, as any selection of radios, chronometers and calculators costing less than £10 testifies.

Obviously the largest mass market for AVL is the private motorist, and if the past history of both instrumental navigation and the application of high technology to consumer goods is anything to go by, we can expect strenuous efforts in this direction. It may be that the most economic way to meet more specialized requirements is to develop around modules designed for the mass market.

Even in the mass private motorist market for location and guidance, a system designed to enable the user to negotiate the 'one-way, no left-turn, no right-turn' systems of a strange city is likely to be quite different from a system to enable one to drive up the front drive of an address such as Willow House, Quarry Woods, near Marlow, Bucks., particularly as the house itself happens to be in Berkshire.

Eventually, I suppose, having accustomed ourselves to including the postal code in our addresses, we shall also add the Ordnance Survey grid co-ordinates. Only eight digits are required to specify coordinates on a 10-metre grid (maximum indeterminacy 7 metres), which happens, quite by coincidence, to approximate to the distance between the prime meridian used by the Ordnance Survey and the Greenwich meridian used by everybody else.

The difference between urban and rural requirements is typical of navigation experience generally. Both at sea and in the air requirements are commonly met by a diversity of complementary systems, and this will doubtless be the case with land vehicles.