Vehicle Tracking and Security

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This paper covers the wide area and short range locational technologies that are available for vehicle tracking in particular and mobile user security in general. It also summarises the radio communications services that can deliver information to the user. It considers the use that can be made of these technologies, when combined with procedures for delivering a response, in the security field, notably in relation to personal security, high-value load protection and the after-theft tracking markets.

1. TRACKING TECHNOLOGY. Most modern radio-based locational technologies rely on determining range to a known point, in contrast to traditional methods that rely on angular measurements. Range determination by radio relies on an accurate knowledge of the effective speed of radio propagation in free space and in proximity to the ground. This speed is required in order to calculate the distance between the source and the mobile antenna. However, the fact that a user knows his location does not provide security in the markets being considered.

1.1 *Satellite systems*. There are two forms of real-time position determination by satellite – passive systems and active systems. Passive systems tend to be military in origin, while active ones are civilian. Points of comparison are given in Table 1.

Passive systems do not require the user to transmit any radio signals. This is necessary for any military user, because radio transmissions can be easily detected by an opponent and not only the user's position determined, but possibly his identity as well. The cost of operating the system is not the highest priority; that is most likely to be its security. This is not to say that cost is irrelevant, but that it is not as significant as it is in a commercial environment. Security of the signal and resilience of the constellation have led both the United States and Russia to much the same conclusion: that a military system should consist of a constellation of around 24 satellites transmitting signals to the user, capable of providing rapid, real-time local position determination. The positioning signals from both these military systems are free to the user and likely to remain so for at least the next 6 years. Naturally the civilian, commercial systems cost money to use. However there is a downside to using military systems; performance may be altered for military reasons.

Active systems require the user to transmit as part of the radio exchange needed to determine location. The operational systems that use this principle in Europe are Euteltracs and Argos, while Orbcomm are expected to announce a service soon. Two Eutelsat satellites are used for Euteltracs with one master satellite providing the message exchange service and a second providing the triangulation required for position reporting. The satellites are monitored and controlled from

TABLE 1. POINTS OF COMPARISON BETWEEN MILITARY AND COMMERCIAL SYSTEMS

	Military		Commercial		
	GPS	GLONASS	Euteltracs	Argos	Orbcomm
Number of satellites	24	24	2	3	2–36
Number of orbit planes	6	3	Geostationary	Polar	4
Plane separation	60°	120°			
Orbit height	20182 km	19200 km	36000 km	LEO	775 km
Signalling	Code Division Multiplex	Frequency Division Multiplexing		400 MHz	137 MHz 148 MHz

Eutelsat's hub in Paris. Coverage extends over Europe and large areas of North Africa and the Middle East. The end user also requires a communications path to the hub. Messages pass between the hub and the target vehicle *via* the master satellite. The position reporting signals pass simultaneously *via* the second satellite. A position is determined by measuring the time difference between signals arriving from the two satellite paths. Eutelsat claim an accuracy of around 80 metres in the centre of the area of coverage, and 300 metres elsewhere. Accuracy will also depend on the speed of the mobile. The Argos system[1] uses three polar orbiting satellites to allow position determination six to twenty-eight times a day, depending on the latitude of the user (about 14 times a day in the UK). The ground transmitter sends data packets every few minutes. When they are picked up by an orbiting satellite and passed to a ground station, the location of the source can be determined. This system is used to track animals and, increasingly, containers in transit. The accuracy of the tracking is around the 1000 metre mark, which is adequate for wide area tracking, but taken with the time between fixes, is not for security applications. Orbcomm is primarily a communications system, but it does include a positioning capability using Doppler ranging and claims an accuracy of between 500 m and 1 km.

1.2 *Terrestrial systems.* Terrestrial systems for vehicle tracking can be divided into the following classes:

(i) Wide area position determination systems;
(ii) Fixed beacons that identify passing vehicles;
(iii) Vehicle-based transponders whose signal can be detected by dedicated readers;
(iv) Self-contained systems that calculate change in position from a known point.

Wide area position determination systems allow the vehicle to know where it is at all times, and do not require data to be passed to a base station or central point before a position is identified. Technical details of such commercially available systems as Datatrak[2] and Loran-C[3] are readily available elsewhere. There is some interest at the moment in systems based on digital cellular phone technology.

Much of this has been generated by the requirement of the USA FCC for 'Phone locations to be given to within 125 metres 63% of the time for all 911 calls' (911 calls are Emergency calls). For networks where the cell size is small (say, around 0·5 kilometre radius), rough positioning is readily available by observing the cell from which transmissions are made. But the methods most likely to produce usable locations are those that measure the time taken to send and receive back a system message between the base station and the mobile unit. From this time delay the range can be determined and, if a number of ranges from base stations are available, a position can be calculated. Measuring the received signal direction is said to be possible, but there will be problems with reflections, and a 1° error will lead to a 262 metre error at 15 kms.

Fixed beacon and tag systems are very useful where there are many items to be tracked in a restricted area or when they move over restricted linear routes. A very basic form is the use of bar codes and bar code readers at suitable 'gateways' in the operational area. More sophisticated systems are available using passive or active tags, or 5·8 GHz systems. One advantage of 5·8 GHz systems is that this frequency allocation is common across Europe, allowing for a common approach. One such system is Tele-Tag from GEC-Marconi Communications. The tag is about the size of a pack of playing cards and contains a code that can be read as it passes within 9 metres of a reader. The tag ID, and any other information passed, is then sent to a central computer by fixed wire, telephone or radio link. In a recent edition of *Automatic ID News*, it was reported that Ford Motor Company is implementing a Prototype Tagging Operation to keep track of expensive prototype vehicles. Tags placed on the vehicles are read at one of the 15 significant entry and exit points around a 5-kilometre site. This system was primarily designed for efficiency of operation in the plant, but it has obvious security benefits. As well as informing people of the approximate location of a particular prototype, the central computer produces management reports that Ford hope will improve utilisation.

Transponder systems have the advantage that the mobile equipment can be very low cost, leaving the more expensive processing to be done in a limited number of base stations. A brief technical description of the following systems is included so that the security implications can be considered:

(i) Pactel Teletrac;
(ii) Quiktrack;
(iii) NexNet;
(iv) Lojack/Tracker;
(v) NetStar.

Teletrac uses 900 MHz spread spectrum transmissions from a vehicle that include identity and status. Transmitted signals are picked up at several base stations where arrival time is added before being passed on to a central location. The difference in arrival time being used to calculate the vehicle position.

Quiktrak uses a similar technique to that of Teletrac, but is usually sold with a communications facility based on paging.

NexNet also uses spread spectrum transmissions from vehicle to base station

to identify a position. In this system, the bearing of the signal is measured at base stations and then passed to a central point for position determination.

Lojack, also known as Tracker in the UK, is targeted at the after-theft tracking market. It differs from the other systems in this group in that the signal transmitted from the vehicle is not intended to be picked up at fixed base stations. The system requires a search vehicle to be equipped with a receiver that can measure the angle of arrival of the signal. A display in the search vehicle will then show the relative direction of the stolen vehicle, while signal strength will indicate the range. This technique has the advantage that it becomes more accurate the closer the search vehicle gets to its target.

NetStar also uses a transponder in the vehicle, with coverage being provided by a network of base stations known as 'signposts' that identify the existence of the target vehicle in the area. To enable the rapid finding of a target vehicle, a helicopter is often employed with an airborne signpost receiver.

Self-contained systems do not rely on any radio infrastructure, but use dead reckoning based on wheel rotation, a heading input and map matching to measure the change of position from a known starting point. This technology is most often used for in-vehicle mapping systems which rely heavily on quality digital databases, such as those from Etak and NavTech. From a security point of view, they have the advantage of being completely passive and will often be an integral part of the vehicle fit. It would not, however, be effective if a vehicle was towed away and the measurements never performed.

2. COMMUNICATIONS SYSTEMS

2.1 *The options.* Systems that allow the vehicle to work out its own position are not of great value in security unless this information can be relayed to a central location. Hence there is a need for a communications path. Again there are a number of options, both terrestrially based and satellite based. The one chosen will depend on several factors including area coverage, service cost and performance. Terrestrial systems are generally cheaper than satellite. If a voice system is in use, it may be perceived as having a 'free' data capability. It is likely that adding data to such a system will either compromise the voice capability or it will not have the immediate access required by security applications. Dedicated data systems are likely to have the lowest operating costs. Satellite systems, by their nature, have very wide areas of coverage that can be important for those who travel widely, or operate in areas of low population density that cannot commercially support terrestrial networks. As they work with very low signal levels, the antenna systems may have to be larger than is desirable for security applications. The options can be summarised as:

(i) Cellular telephony;
(ii) Private or Public Access Mobile Radio: Dedicated radio schemes; Band III; Tetra/Tetrapol;
(iii) Mobile Public Data Networks: Mobitex (Ram): Cognito; Vodafone Data Networks (Paknet); Datatrak;
(iv) Satellite services.

2.2 *Cellular telephony.* There are two main standards in use, spread over

several networks and several names. They are referred to as Global System for Mobile Communications (GSM) and Digital Communications System 1800 and 1900 (DCS 1800 and DCS 1900). They are capable of digital message communications, with short data packets and larger packet data transfer. The choice of information flow is dependent on the service required and how much the network operator charges for the data packet. For the applications discussed in this paper, the cost will usually be the lowest available charge. This will often be the communications path of choice when it is necessary for the mobile to have a voice path. The disadvantage can be the costs of regular reports. Coverage is good in densely populated areas, but can be problematical away from major towns.

2.3 *Private or Public Access Mobile Radio.* Private Mobile Radio has been around a long time, especially as analogue schemes in the utility companies, such as the water, gas, electricity and nuclear industries. They are primarily provided for voice access and regard the provision of a data capability as being a free upgrade. Care must be taken to avoid overloading the radio network, as planners rarely over-estimate the usage of data. The caveat of mixing data and voice over a single channel must be borne in mind. Public Access Mobile Radio, such as Band III from Geotek Industries, has a local area data capability and provides a fixed price service for voice and data. TErrestrial Trunked RAdio (Tetra) and Tetrapol from Matra Communications are emerging standards competing for the same market area. Tetra is a European Standard and is the basis for the Public Safety Radio Communications Project (PSRCP), that is intended by the Home Office to provide a common voice and data capability to the emergency services of the United Kingdom from about 2001. The primary drivers of the PSRCP are the needs of the police service. Tetrapol is operational in the Paris area for rail services and is competing for market share with Tetra.

2.4 *Mobile public data networks.* These systems are of great value to organisations that are not large enough either to have their own wide area communications network or do not have their own radio expertise. They may require a fixed price communications service or need rapid response to an incident for security purposes. Such data networks are optimised for packet data and hence are inherently secure, again of value in security. There are, in my estimate, some 120000 users of mobile data in the UK, about 45 percent using Vodafone Data Network and the rest split between Band III, RAM, Cognito and Securicor Datatrak. The choice between these service providers will be based on cost, performance and coverage.

2.5 *Satellite services.* There are only two major providers of data communications in the European area at the moment, Inmarsat and EutelSat. There are, however, many other Service Providers about to announce, or who have already started to launch, their satellites.

3. ASPECTS OF SECURITY. Three key areas of security where vehicle tracking systems can have a significant impact are:

(i) personal protection;
(ii) high value loads;
(iii) after theft tracking.

3.1 *Personal protection.* In looking at personal protection, it is necessary to define exactly what threat we are addressing. The threat may be a risk to the health and safety of a worker, it may be the possibility of kidnap for ransom, the holding of a hostage in order to force others to carry out certain actions or simply a threat to a person for theft. In a completely different area altogether, it could be an elderly or infirm person living alone who needs to be able to call for help from any room in the house. The degree of threat to a person varies greatly throughout the world. For instance, the threat of kidnap is not great in the UK, but can be higher in other, less stable countries.

The aspect of security with the widest application, certainly in the UK, is the health and safety of lone workers. This has taken on a wider significance throughout Europe, following the increased focus on Health and Safety at Work legislation. Whilst this legislation has been on the books in the UK for a number of years, people from both sides of industry are becoming increasingly aware of what can be done to protect lone workers and are, consequently, demanding that it is done. From the aspect of this paper, we can say that to provide the lone worker with protection, it is necessary to be able to rapidly identify and locate him following an incident or accident. There are a number of systems in the market place that address the problem for those workers who move around a specific site, such as a prison or chemical plant. These buildings or factory complexes are usually equipped with a short-range wireless system, using a fixed-wire infrastructure. The sensors can detect a panic button press, use lack of motion for a defined period of time or detect that the user is lying on the ground. Industrial plant workers will not usually use vehicles to move around and so this equipment must be portable and hence of lower transmission power.

Now that the vehicle tracking systems are widely available, lone worker protection can be provided to many more people. Any person who uses his vehicle as part of his job can be protected. This includes workers in the gas, electricity and water supply industries; engineers in telecommunications; drivers in the transport industry, building society and bank managers; high value goods vault key-holders, as well as security guards. Health workers who travel alone, especially nurses, can also be included if they are felt to be at high risk. The equipment, being vehicle-based, can have a higher transmitted power and hence have a greater range. The sort of device that they need is similar to that used by the prison guard or petro-chemical plant worker. They would have a button to press in an emergency and a means of detecting when they become immobile. This type of protection also requires a means of getting this essentially short-range information back to a central point many miles away. Hence the value of using a vehicle tracking system as a relay and, fundamental to the choice of communications bearer, will be the coverage provided by the service. Blick *alarmtrack* is part of a range of personal protection systems being offered using the Datatrak network. Such systems allow a user to initiate a call for help in several ways even when they are up to 800 metres away from their vehicle.

3.2 *High value loads.* The definition of a high value load may differ from one country to another, depending on local taxation, local shortages and demands. From a security point of view there are two main approaches – it can be achieved

by hiding the load or publishing the fact that it is well protected. Securicor use the latter approach with their Cash In Transit (CIT) fleet-purpose-built vehicles that make it clear to whom they belong and what they are – and they all carry Datatrak advertising! A look at the outside of the vehicle shows that they are of very strong construction and are protected by bullet-proof glass, they have reinforced side panels and are proof against chain-saw attack, whilst valuables can only be loaded or unloaded through a rotating safe with a time-delay mechanism. But no matter how much ingenuity has gone into their construction, CIT vehicles can always be subject to duress attacks. A crew member may be held at gun-point to ensure the co-operation of those who have access to the internal safe. This type of attack may take those involved a significant amount of time, as it is likely to involve taking the vehicle to a secluded place. During this time the control room operator can track the vehicle and alert the police. The other method of providing security is by preventing the criminal fraternity from knowing which vehicle is being used. Some high value load carriers use unmarked trucks and articulated trailers, while still fitting them with sophisticated tamper detection and tracking devices.

3.3 *Car theft – the problem.* Car theft is a major problem throughout the world. In Europe, 1 312 863 vehicles were stolen in 1995 and of these only some 790 058 (60 percent) were recovered.[4] The remainder may have been taken to another country, 'ringed' or broken up for sale as spares. The proportion never recovered is not constant across Europe and the position in other continents varies greatly, as the figures from South Africa show (Fig. 1). The only conclusion

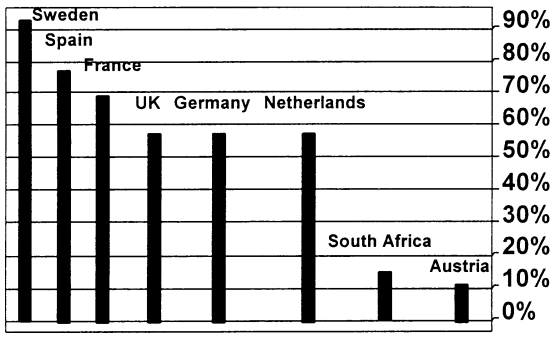

Fig. 1. Proportion of stolen cars recovered

that can be drawn from the Austrian figures is that the country has many borders with ex-communist countries.

The United Kingdom Home Office figures show that in 1996, 493 302 vehicles were stolen. The UK has the worst record in Europe for car crime, with 22 cars stolen for every 1000 on the road. Only France, with approximately the same number of vehicles on the road, approaches these numbers, with 11 cars per 1000 stolen. Italy, with 30 million vehicles, has 10 per 1000 stolen. UK car theft is thought to cost £2.3 billion pounds a year, while truck theft is put at £600 million and plant theft at £500 million.

3.4 *Car theft – some solutions*. In the face of such a universal problem, what types of tracking and identification technology can help? Such systems can roughly be divided into two groups: Short Range Point Identification, and Wide Area Tracking systems. The European Technical Committee 278 Task Force report[5] on tracking systems identified by functionality, the following different types of system.

(i) vehicle recording systems (VRS);
(ii) vehicle identification systems (VIS);
(iii) vehicle remote immobilization systems (VRI);
(iv) vehicle signalling systems (VSS);
(v) vehicle location systems (VLS).

The Task Force is now constituted as a Working Group (WG14) and is trying to agree standards for all types of tracking system. All the systems mentioned above have an on-board electronic device that provides the functionality and radio communication capability. The first two types are nearly always short-range devices, while the last three are usually wide area, long-range systems. However, generalisations can be misleading in this market. Short-range systems allow the identification of a vehicle from within a few metres, while longer range systems can identify either the absolute location or relative location to another location.

3.5 *Vehicle Tracking Systems*. I am focusing here on VLS systems; that is, systems in which the absolution location of the vehicle can be established. It is easy to call these systems 'anti-theft', but a tracking system is not, in itself, an anti-theft system. It can only achieve this status if it includes something like an immobiliser to prevent the vehicle from being stolen in the first place. From the purchaser's point of view, they would rather still have use of their vehicle, than be able to track it after it was stolen. There are a large number of systems on the market that address the after-theft tracking market. The majority of those commercial sold have a vehicle immobilizer as part of the fit. The list in Table 2 is not comprehensive, but it does give an idea of the growing interest that exists in this market place.

About two thirds of these systems are a combination of GPS and a cellular phone system, and another two-thirds are, I believe, still only paper products. It is important to recognise that just putting together a number of electronic boxes does not make a product acceptable to the market. The complete system must be able to deliver the service required by the purchaser, to identify the vehicle, find it, get the law enforcement agency officers to the scene and return the vehicle to its owner.

If we consider the complete system that provides a service to the end user, be they a private motorist or commercial operator, we must define who is going to do the tracking, who is going to do the finding and who is going to do the recovery. There is no one common answer to this in all parts of the world, since what works in the UK might not work in other parts of Europe or the rest of the world. Here in the UK, we can rely on the police to react quickly to a report of a theft in progress, where there is a good chance of an arrest and useful improvement in crime statistics.

Table 2. Vehicle tracking systems

Product	Origin	Product	Origin	Product	Origin
Alcatel	D	Lojack	USA	Serpispace	Italy
Aldiscan	Eire	Mayday	USA	Skeye	NL, D
Argos	USA F	Netstar	S Africa	Skyguard	UK
Auto-alert	UK	Mobitracer	NL	Skynet 2000	UK
Autoguide	UK	Msts	NL	Skytel	USA
Avid	UK	Navtrax	USA	Spy	USA
Carangel	NL	Nightwatch	UK	Startrack	UK/USA
Cel Trak	Eire	Nusafe	D	Street Guard	D
Cel Track	SA	Onstar	UK	Tardis	UK
Cellutrac	USA	Orchid	UK	Tel Cel	
Cellway	F	Pegasus	USA	Tele aid	D
Clos	NL	Pinpoint	UK	Teletrac	USA
Cobra	UK	Private Trak	UK	Terrapin	USA
Cursor	UK	Quiktrak	Australia	Theft-Sat	USA
Demonscan	UK	Rescu		Tidget	USA
Detback	F	Recall	UK	Tracer	UK
Duo	SA	Satcon	Germany	Tracker	UK
Eagle Eye	UK	Satsting	Canada	Trackman	USA
Fleet Track	NL; Kenya	Sattrak	UK	TrakBak	UK
G-Track	SA	Seaboard	UK	T-traffic	D
Globaltrax	CAN	Selectronic	D	Vsta	USA
				Xc Refinder	NL

All trademarks in this list are acknowledged.

3.6 *After-theft systems in the UK.* In the UK, the Association of Chief Police Officers (ACPO) Property Tracking Group, in conjunction with the vehicle tracking industry, has produced a set of operating guidelines for the after-theft tracking market. It requires that the tracking bureau meets certain standards before operating a service, but also guarantees nothing:

> The Police response to a suspected crime is an operational matter, and is subject to the discretion of Chief Officers and competing operational commitments.[6]

ACPO guidelines state that the theft must be reported to the police by the owner and a crime number obtained. Once this is done, all information can be entered onto the Police National Computer (PNC). Then, when the bureau pass vehicle data to relevant Police Control Room, using the defined special phone number, all the information that the police have on the crime can be easily accessed. In practice, the report of a suspected (that is, unconfirmed) theft often produces a quick police response and Securicor TrakBak report an average recovery time of 60 minutes.

SUMMARY. The proliferation of products that have been announced indicates the belief by the business community that a market exists for many types of tracking systems that not only address security but also provide breakdown or medical assistance as well as information on facilities close to the vehicle. However, from the many types of locational and communications technologies

available, the one chosen for mission critical applications must depend on accurate position determination and reliable communications to produce an effective response. Having identified the threats in respect of personal security, high value load protection and after-theft vehicle tracking, it is critical to choose the product that is appropriate to meet the particular threat. The product must, of course, be fully operational and not merely a promise.

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KEY WORDS

1. Communications. 2. Land. 3. Navaids. 4. Safety.