

Science in the service of crime reduction

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Klaus Schmidt...burst into a bank in Berlin in August 1995, waved a pistol and screamed 'Hand over the money'. Staff asked if he wanted a bag, to which he replied 'Damn right it's a real gun'. Guessing Schmidt was deaf, the manager set off the alarm, saying later 'It was ridiculously loud, but he didn't seem to notice'. After five minutes, punctuated by Schmidt occasionally shouting 'I am a trained killer', police arrived and arrested him. Schmidt then sued the bank, accusing them of exploiting his disability (Moore 1996: 11).

The idea of outsmarting criminals has general appeal. Television programmes such as *America's Dumbest Criminals* permit a feeling of superiority in the viewer. We find newspaper stories of burglars who photograph themselves at the scene of their crime, and bank robbers who write their demands for cash on the back of self-addressed envelopes. These invite ridicule of those who might otherwise be feared, and feeling superior to the inept criminal sits uneasily with feeling threatened by and vulnerable to them.

A less direct but still powerful means of asserting superiority over criminals is to outwit them. Within police work, the usual instrument is the 'sting' operation, where (for example) those on outstanding arrest warrants are notified that they have won a lottery prize, and are invited to collect it. At the collection point, they are arrested.

A still less direct means of asserting superiority involves the use of science. If the techniques of this most admired of human activities can be brought to bear on crime reduction, then (the citizen opines) virtue may yet prevail. The writer knows of no research which clarifies such beliefs and feelings. Speculatively, stories of offender ineptitude and police stings have the attraction of being accessible. What happened is clear. Stories of science applied to crime are less accessible, but have a compensating glamour and mystery and feature extensively in television schedules (there were two such programmes in the schedules on the night when this was written, 31 January 2005).

This chapter aspires to do three things. First, it seeks to outline the range of scientific endeavours which are self-consciously applied to crime control; in other words what is the science currently deemed relevant. Secondly, it considers whether there are other areas of scientific endeavour which are potentially relevant, or other ways of thinking about the application of disciplines already seen as relevant. Thirdly, it addresses the issue of how 'hard' science may interact with conventional criminology to increase its impact. *En passant*, it notes:

- the extensive self-protective effort expended in military and commercial contexts, and considers how such applications may 'trickle down' to general application in crime control; and
- the obstacles to bringing science-inspired crime reductive products to market.

The current range and status of science within the Home Office

The Home Office is the government department which is responsible for crime control within England and Wales. The first three of its declared aims are as follows. The first two are deemed central to the coverage of this chapter, the third marginally so. To:

1. reduce crime and the fear of crime, tackle youth crime and violent, sexual and drug-related crime, anti-social behaviour and disorder, increasing safety in the home and public spaces;
2. reduce organized and international crime, including trafficking in drugs, people and weapons, and to combat terrorism and other threats to national security, in co-operation with EU partners and the wider international community; and
3. ensure the effective delivery of justice, avoiding unnecessary delay, through efficient investigation, detection, prosecution and court procedures. To minimize the threat to and intimidation of witnesses and to engage with and support victims.¹

Its website² is therefore as good a place as any to see how it invokes science in its work. Searching on the keyword 'science', we read as introduction:

The Home Office undertakes a huge range of scientific projects to support its work. Recent projects include measuring the effect of treatment initiatives on drug users, researching biometrics for ID cards and investigating whether tasers can be used safely by the Police. The results of this scientific work are used to inform policy and make sure that the Home Office is making the best use of new technologies.

Seven of the first ten matches 'by relevance' feature the Forensic Science Service. Thus forensic science seems to have primacy at least in terms of this simple check. However, the links from Science in the Home Office home page invokes a number of other Home Office locations as having science relevance. These are listed in Table 7.1, which is thus a crude enumeration and description of science-based activities done by and for the Home Office. In some of the linked sites the activity is transient and concentrated on training (as in the forensic pathology case), in some cases it focuses more on social than physical or biological science (exclusively in the Youth Justice Board site, and overwhelmingly in the Research Development and Statistics Directorate). In some cases the relevance of the cited science to the Home Office aims centred upon crime and noted above is not detailed. The Immigration and Nationality Directorate's involvement with science seems limited to its choice of iris recognition as the intended biometric means of unique personal identification (although historically social science work has featured in the research portfolio of the Home Office Research and Statistics Directorate).

Exploring the relevant websites and downloadable documentation makes two things clear. First, it seems that the research programmes are not substantially cross-referenced. The cynic's view of this state of affairs would be that the programme is not fully integrated. The apologist's view would be that each group serves a particular market precisely. That there are recurring themes across at least some of the units and groups mentioned here is clear, the three most obvious being the unique identification of people (and to a lesser extent things, especially drugs), the tracking of people (and to a lesser extent things, especially consumer products) and the development of telecommunications. The lack of cross-referencing across parts of the Home Office even when the theme is the same inclines one towards the cynic's view.

Limiting discussion in this chapter to the role of the Home Office neglects the wider issues of integration across government departments, since many crime issues are facilitated or constrained by the decisions of departments of state from education to the Exchequer. It may be that the prospect of the possibly cataclysmic effects of CBRN (chemical, biological, radiological and nuclear) attack will expedite cross-departmental co-operation, and that this will operate through (or incidentally affect) the regulation of volume crime. For the moment, attention will be restricted to intra-Home Office matters.

It is certain that the Home Office recognized the fragmentation of scientific effort as sub-optimal. Three recent events support such an interpretation:

1. The Head of the Research, Development and Statistics Directorate was designated Chief Scientific Adviser to the Home Office, with overarching responsibility for all science activities.
2. The Police Scientific Development Branch is to be retitled the Home Office Scientific Development Branch, with a correspondingly wider mandate for applied research.
3. Two police 'science strategy' documents were published.

Table 7.1 Home Office science links

Name	Description	Web address (prefixed by http://www)
Animal Scientific Procedures Division	Regulates use of animals in scientific procedures	homeoffice.gov.uk /inside/org/dob/direct/aspd.html
The Forensic Pathology Review Implementation Team	Concerned with the provision of forensic pathologists	homeoffice.gov.uk /inside/science/forensic.html
Forensic Science Service	Supply of forensic science services to police forces in England and Wales	forensic.gov.uk/forensic_t/inside/about/index.htm
Information and Communications Technology Unit	Responsible for support of police telecommunications, information technology and radio engineering	homeoffice.gov.uk/inside/org/dob/direct/ictu.html ¹
Immigration and Nationality Directorate	Responsible for immigration control	Ind.homeoffice.gov.uk/content/ind/en/home.html
Police Information Technology Organization	Provides information technology and communication systems to the police and criminal justice organizations	pito.org.uk/
Police Scientific Development Branch	Provides impartial and accurate scientific and technical advice to the police and ministers; improving police operational effectiveness and efficiency	homeoffice.gov.uk/inside/org/dob/direct/psdb.html
Research, Development and Statistics Directorate	Maintains statistics published by the Home Office, conducts economic analyses and carries out and commissions social science research	homeoffice.gov.uk/inside/org/dob/direct/rds.html
Science Policy Unit	Develops and delivers policy on police use of science and technology	homeoffice.gov.uk/inside/org/dob/direct/spu.html
Youth Justice Board	Researches what works in reducing youth crime	youth-justice-board.gov.uk/YouthJusticeBoard/Research/

Note:

1. This may no longer exist by the date of publication. Mention of it is retained to give the fullest possible depiction of the state of affairs at the time of writing.

Whilst these changes will doubtless diminish fragmentation of effort somewhat, they represent, as the Home Office would certainly acknowledge, only a promising first step in its ongoing process of integrating science activities. For example, the Crime and Disorder Act 1998 conferred responsibility for local crime and disorder reduction upon local partnerships (CDRPs), including local authority and police representation. In logic, the science strategy mentioned above should incorporate CDRP interests. If the partnership is the responsible agency, the partnership should receive scientific support. In partial mitigation, the restriction of the document to police concerns stems from its origins in the police reform process.

Although one may question its restriction to the police as a customer agency, the science strategy is admirable in its integrative intent (and future orientation, the first explicitly covering a period to 2008 and establishing a future scanning function) and merits discussion at some length. Information and communications technology (ICT) and forensic science are the areas singled out for special mention, with the catch-all 'other technologies' added. The primacy of these topics is evident in the specific goals for policing technology which are mentioned, and in the areas identified as profitable for Home Office research sponsorship (Home Office 2003: 13), which are all concerned with the unique identification of people, products or drugs:

Over the period of the plan the police service, working as necessary with its criminal justice partners, should by:

- 2003 have secure e-mail facilities across the Criminal Justice System.
- 2004 have the profiles of the whole active criminal population on the national DNA database (currently projected to be 2.6 million offenders by 2004).
- 2005 complete the roll-out of Airwave, the new police radio communications service.
- 2005 have begun to enable victims to track progress of their case on-line.
- 2005–06 ensure that the Case and Custody system is implemented in every force, with links to courts and the Crown Prosecution Service. (Home Office 2003: 9).

Figure 7.1, reproduced from the strategy, details 'key stakeholders'. The figure is interesting for several reasons. First it acknowledges the role of a large range of agencies³ recognizing the basic argument, to be developed later in this chapter, that the levers on crime incidence are primarily outside the police and criminal justice networks. Secondly, it assigns 'stakeholders' to one of two roles, either service providers or 'key links'. Service provision is clear from agencies like the Forensic Science Service to the police. The area of remaining doubt in making such service as up to date as possible is how the key links might work. What services do 'academia, industry, and international sources' provide directly to the police? Why are there are no updating or other services

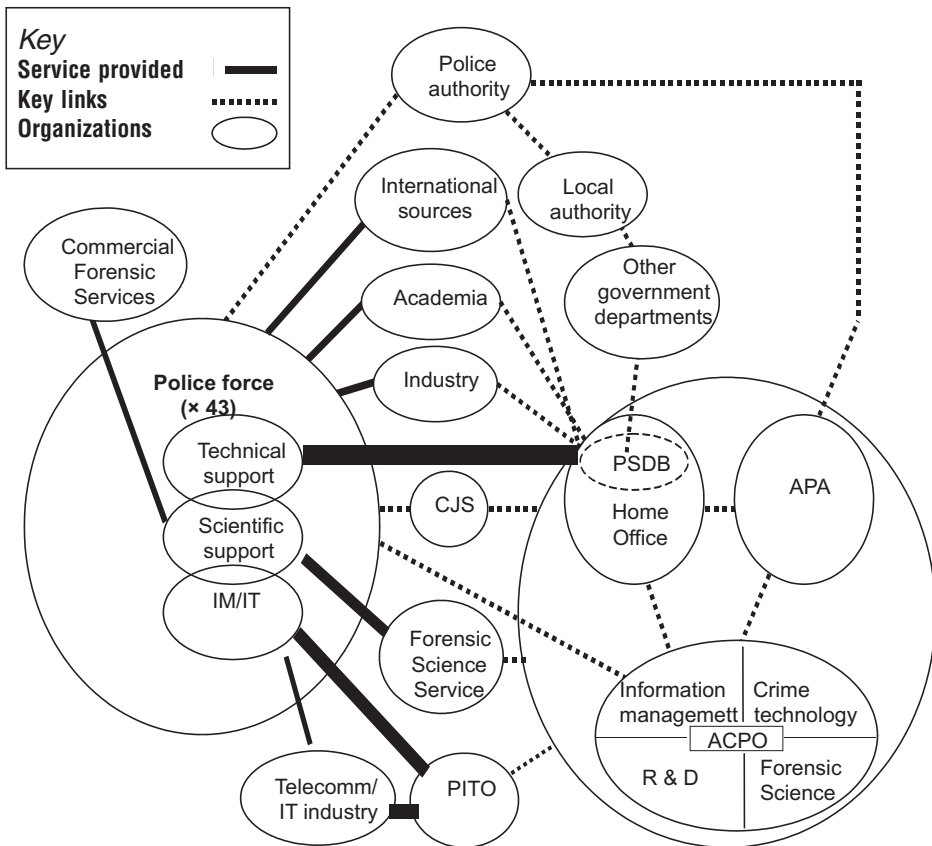


Figure 7.1 Key stakeholders in police science and technology
 Source: Adapted from Home Office (2003)

to the Home Office? Why are the constituent parts of the Home Office linked to each other and the constituent parts of the police service not similarly linked? Why does the telecommunications industry (depicted separately from industry generally) have no identified links to the Home Office? One could continue to dissect the figure and identify more unresolved issues and oddities, but the purpose here is not to bury the strategy but to praise it as a very useful first step in a hitherto fragmented domain. The figure reflects that and, as the strategy document makes clear, was intended only as ‘a much-simplified representation of the complex relationships between the key organisations involved in the provision of police science and technology’ (p. 8). Further, some modest clarification of the figure is provided in the text.

The successor strategy document does not, in the accompanying letter from the Minister of State, ‘represent a dramatic change of direction from the original’. The emphasis on post-crime science is maintained, but the report’s Appendix 4 does represent both an increased diversity of projects and a higher proportion of them under the ‘Crime Reduction’ heading. The enhanced role of automatic number plate recognition is notable and welcome, together with the emphasis on the real-time establishment of identity.

A crude measure of the relative emphasis on reduction and investigation can be gleaned from the number of items listed in Appendix 4 as components of police science and technology capabilities classified under 'Reduce Crime' relative to those listed under 'Investigate Crime'. There are 16 under the first and 22 under the second, and arguably many of those classified as 'Reduce Crime' involve action after a crime has taken place (e.g. those involving the monitoring of known offenders and the use of CCTV in detection and prosecution). In the strategy document's Appendix 7, we find the conclusions of the Future Scanning Sub-group, which identifies 'those developments which are most likely to impact on policing over the next five years' (p. 41). These (with brief illustrative quotations) are as follows:

- *Biometrics*: 'The threat of criminal subversion of biometric systems... could make identity theft a much greater threat'.
- *Electromagnetic imaging*: 'These are emergent technologies... whose value could be great, particularly for security applications. One of the main opportunities for application is in screening for weapons, explosives etc. in airports.'
- *Encryption*: 'The use of encryption provides capabilities that can be viewed as... negative when employed by the criminal.' The debate concerns the police right to hold encryption keys for secure communications between citizens, and the possible criminal use of steganography and quantum cryptographic techniques.
- *Geo-location*: 'This term encompasses... technologies to locate people, vehicles and other assets.'
- *Lab-on-a-chip*: 'the miniaturisation of existing chemical or biochemical synthesis, detection and analysis procedures.' This would allow rapid crime scene analysis of forensically relevant material. Noteworthy is the recommendation that a 'working group should be set up to keep the crime relevance of the technology in the minds of the developers'.
- *Third generation of mobile phones*: New software will enable a reduction of the number of stolen mobiles purchased for criminal activity, by detection of theft and de-activation. 'It is important to work with industry and existing bodies to identify threats and opportunities at an early stage.'

Although the second strategy document moves towards integration, a developing theme of the chapter is that the thrust of hard science is primarily directed towards a narrow range of topics, amongst which unique identifiability and telecommunications in the service of the police and courts are pre-eminent. This was anticipated some 30 years ago by Leslie Wilkins. In an astonishingly prescient paper in 1973 entitled 'Crime and criminal justice at the turn of the century', he bewailed the application of science to the establishment of guilt rather than to crime prevention. He wrote as if he were already at the turn of the century, and concluded that

There has been little development of technology which makes crime more difficult; techniques have been concerned with the various aspects of the finding of guilt and the allocation of blame. Fingerprints, voice-prints, lie-detectors and the like help only in pinning the blame more certainly upon the person who has already been suspected. Even the modus operandi index is used to identify persons who may have committed the crime, rather than for the purposes of preventing further crimes of a similar nature (p: 22).

The primary reasons for the state of affairs which Wilkins foresaw are twofold. First, his was a soaring intellect. Secondly is the nature of the market in crime reductive products, which is driven directly and indirectly by the police service. The direct role comes via its own procurement of systems like the Airwave radio system and advanced fingerprint analysis. Its first indirect role comes through its demand for forensic services, primarily through the Forensic Science Service, the Forensic Alliance and the LGC (as the Laboratory of the Government Chemist is now known). Its second indirect role comes through its (generic) recommendation of products and services available to the public or commercial organizations, for example by its incorporation into the advice of police crime reduction officers. The service is scrupulously careful about endorsing individual products in a competitive market, but recommendation of products with particular technical features and meeting standards drives the range of available products.

First stirrings of a wider view of science relevance

The contrast between the first and second editions of the police science technology strategy lies in a movement towards a wider and more balanced use of science in crime reduction and crime investigation.⁴

Marcus Felson's routine activity theory (see Felson 1998) identifies three necessary conditions for a crime to occur. They are the coincidence of:

- a motivated offender, and
- a suitable victim, in the
- absence of a capable guardian.

Although this formulation seems anodyne, even self-evident, its implications are surprisingly profound. As science and engineering transform society, each of the three necessary conditions changes, as does the meaning of coincidence. For example, victims of theft are suitable when they carry items with particular characteristics, summarized by the acronym VIVA. To be attractive to thieves, objects must be high in Value, low in Inertia and Volume, and moderate in Access.⁵ Mobile phones in the 1990s and i-Pod devices at the time of writing are classic VIVA items, with the i-Pod having the advantage of a distinctively coloured headset so as to be identifiable even when the device itself is out of sight, presumably so as to confer prestige on the wearer. Ekblom (2004: x) puts it well:

Social and technological change moreover constantly creates new opportunities for offending – new targets (mobile phones and laptops), new environments (cash machines, shopping centres, financial networks in cyberspace), new business models (e-tailing), new tools (such as cordless drills, spray cans, colour photocopiers or easy-to-fly airliners) and new information sources (how to pick locks or make explosives, courtesy of the Internet) which may mean a wider circle of offenders acquire ‘expert’ techniques.

The other profound change of recent years has been in the possibilities for coincidence of offender and suitable victim. The potential afforded by the postal service, the telegraph and the telephone in bringing offender and victim together have paled into insignificance alongside that afforded by the exploitation of cyberspace. The migration of crime from meatspace to cyberspace is one of the major features of the modern world,⁶ with the following advantages for the offender:⁷

- The ready and simultaneous access to millions of potential victims or potential co-offenders, whose interests and sensitivities are reflected in their presence in chatrooms and user groups (for example adolescents in ‘flirty’ chatrooms, vulnerable to sexual predation; people interested in synthesising narcotics; see Schneider 2005; people competing as a skill to gain illicit access to services, such as satellite TV; see Mann and Sutton 1998).
- The ready and simultaneous access to millions of computer systems which can be compromised by Trojans, worms, etc., either to yield money or as an expression of malice.
- Ease of dissembling about oneself (and perhaps adopting multiple identities), for example a sexual predator pretending to be of similar age to potential victims, or a fraudster pretending to require money to release a huge legacy.

In short, the scope of science and engineering relevance is potentially much wider than as a means of intervening after the fact. The simultaneous recognition of the wide implications of science change and the relatively narrow focus on policing response is encapsulated in the first two paragraphs of the Minister of State’s Foreword to the first Home Office strategy document cited above:

- i. Society, as a whole, is experiencing rapid and accelerating change. In a relatively short space of time our reliance on science and technology has increased dramatically in both the work place and in our homes. Mobile phones, the Internet (and computers more generally), laptops and electronic organisers are for many part and parcel of daily life. These new technologies provide many benefits – but they also provide new opportunities for abuse and criminal exploitation.

- ii. I want to ensure that the police service is equipped with the best tools and techniques available to enable them to work with maximum effectiveness and efficiency. From the very start of the police reform process it has been clear that a more strategic approach to science and technology was needed and we made this one of our key commitments in the white paper: *A Blueprint for Reform*. For the first time this strategy presents an overarching vision of how we will address not only our immediate policing needs, but also the capabilities the police will need in the future (p. i).

It may be unfair to label this Foreword as schizoid, since the strategy outlined was a policing strategy specifically, and indeed one of the elements in the strategy was an orientation towards future trends. However, it should perhaps have pointed to the need for a wider strategy on science wherein police investigative needs featured less and crime reduction needs featured more. To the observer, the migration of crime to cyberspace calls into question the whole balance of effort between crime reduction organized territorially and globally. One police officer friend spoke with appropriate contempt of a questionnaire he had been invited to complete asking 'How much Internet crime takes place in your area?' The establishment of the Hi-Tech Crime Unit (NHTCU)⁸ is one straw in the wind suggesting that the balance of effort is changing to meet the changed challenge. The direction of change in the second police science strategy compared with the first is an even more important one.

Perhaps a crucial element in seeing science as aiding policing rather than shaping crime has been the pace of change in crime, and the way in which shoe-horning the rich diversity of criminal action into the arid and uninformative categories used by the Home Office serves to obscure what actually happened; who did what to whom in what context. The recognition that standard crime categories are fundamentally unhelpful for purposes of crime reduction (including the involvement of science to that end) is so central as to merit some expansion.

Whilst the first nine decades of the twentieth century showed a consistent year-on-year increase in the volume of recorded crime, and whilst any short period does not yield major qualitative change in crime, it is possible to overlook the fact that over the centuries the acts that get squashed into relatively unchanging crime categories have altered almost beyond recognition. Whilst tomorrow's crime is judged likely to be similar to yesterday's, what needs to be avoided remains unclear.

Table 7.2 details what is stolen in offences coming to the attention of Black Country courts in 1835–60. It will be seen that the theft of animals predominates, with theft from employer and theft of fuel also major reasons for coming before the court. There was no instance of theft of or from motor vehicles, or theft of video equipment, which together now account for nearly half of all thefts suffered according to the British Crime Surveys of recent years.

Until perhaps a decade ago, thinking about future crime tended to focus on future criminality and its detection rather than on the crime event. This tendency to focus on the future of criminality and responses to it, rather than

Table 7.2 Black Country theft 1835–860

Type of theft	%
Theft from place of work	28
Theft of food or clothing	25
Theft of animals	7
Theft of or from motor vehicles	0
Theft of video/audio equipment	0

Source: Modified from Philips (1977).

to anticipate changes in crime itself, even extends to fiction. The science fiction and fantasy literature concentrates upon criminal justice (see, for example, Olander and Greenfield 1977). The best-known science fiction work is Isaac Asimov's detective Elijah Bayley, and his robotic sidekick. Prediction of crime types and extents is thus, for all practical purposes, not part of criminology, traditionally conceived. The one book whose subtitle suggests that its contents should deal with future crime rather than future justice is *Visions for Change: Crime and Justice in the Twenty-first Century*. This book (by Muraskin and Roberts 1996) does not fulfil the promise of its title.

Whilst the self-conscious anticipation of crime trends is almost wholly missing from criminology literature, some work is usable for prediction purposes and may have been carried out with half an eye to prediction. For example, Simon Field's demonstration that economic cycles bring crime consequences, with property crimes rising at times of recession, and crimes of violence during more prosperous times (Field 1990), affords a predictive tool of sorts. However, even this operates with gross measures of crime and its predictive use is only implicit.

Just as criminologists have by and large neglected the future, so futurologists have largely neglected crime. None of the books in the World Future Society's bookshop bears a title which suggests it deals with crime (Future Times 1998). None of that Society's 'Sixty-five forecasts about your future life' deals with crime (*Futurist* 1998). Peter Cochrane is perhaps currently the UK's leading futurologist. His writing is unfailingly stimulating and shrewd. However, in his *108 Tips for Time Travellers* (Cochrane 1998), crime appears only twice in the index of the 227-page book, once in relation to encryption, and once about pornography.

In the future, human cupidity and aggression, distributed unevenly across people, can be assumed. People will pursue self-interest by force or fraud. Many of the ways in which they do so will be familiar from the past. Partners will still assault each other. People will steal from each others' homes and places of work. They will do so to a large extent rationally (see, e.g. Cornish and Clarke 1986). They will steal away from the gaze of people and cameras, they will steal goods which they will themselves enjoy using or can sell on. They will arm themselves with weapons which, whilst not exciting, are capable of causing harm of at least the level desired. Because of their rationality, the extent to which and the ways in which they commit crime will depend upon

the kinds of behaviour which social and physical arrangements favour. Crime will remain the hum in the machine of emotional, social and economic life. It is unquestionably more profitable to examine the criminal opportunities which a future society will offer, and the ways in which science and technology can reduce or eliminate these, than to look at possible people change, either through socialization or the effects of criminal justice.

The group within the Home Office which brings the broadest range of sciences to bear upon policing is without doubt the Police Scientific Development Branch, soon to be redesignated as the Home Office Scientific Development Branch, in line with the trend discerned above in recognition of the fact that progress shapes crime as well as responses to it.

The Foresight programme

The Foresight Crime Panel was one of three cross-cutting panels which the Department of Trade and Industry established in its second phase of work in 1999 (the rationale for the panel is spelled out by Rogerson *et al.* 2000). Conventionally, such panels cleaved to industry divisions (such as insurance, financial service and the like) which sought to identify developments in science and technology which would alter the industry landscape. Crime was included as a special case in that, as Marcus Felson (1998) makes clear, trends in every segment of commerce would determine the supply of criminal opportunities. The two reports of the panel (DTI 2000a, 2000b) remain of relevance both in their own right and as stimulating later developments.⁹

The paraphrased recommendations of the panel will be listed, with an indication in each case of how the recommendation was reached.

That a dedicated funding stream be established to focus science and technology attention on crime reduction. This recommendation flowed from the recognition that work funded by the research councils and which were specifically crime oriented were overwhelmingly concentrated in the Economic and Social Research Council. This was recognized as an over-statement of the position, in that work of crime relevance was done elsewhere but classified under another heading. However researchers from other science disciplines commented on the absence of a crime motif in their work. The lack of a funding focus for such work was implicated, as was the difficulty of obtaining sympathetic peer review for cross-cutting work, since reviewers were (almost by definition) selected for the distinction of their work within a discipline. The recommendation led, more or less directly, to a funding stream established by the Engineering and Physical Science Research Council, whose content will be illustrated later in the chapter. The procedure by which the Police Science and Technology Steering Group works to keep focal the crime relevance of lab-on-a-chip development is also an indication of the same process of thought as the Foresight group displayed. In parallel, the involvement of the Design Council and the Royal Society of Arts in stimulating work into crime-reductive design are also developments which were set in train or speeded by the Foresight work.

That a national e-crime strategy be established for all levels of e-crime. The panel noted initiatives in this direction, but contended that the work primarily focused on high levels of organization of such crime (for example, the National Crime Intelligence Service (NCIS) Operation Trawler). It was not convinced that comparable attention was given to crimes against individual citizens, and saw such crime as hampering the development of e-commerce. The establishment of the national office of E-Envoy is a step towards this, with a private company, Entrust, contracted to manage government Internet security. However, the risk in card-not-present frauds¹⁰ suggests that, in relation to e-commerce, the panel's concerns were well founded.

That the wider impact of new technology on the criminal justice system (CJS) be reviewed – including training, equipment, funding, co-ordination and consistency, and action taken to address the issues identified. The absence of connectivity amongst police forces and between police and other players in criminal justice concerned the panel. The independent purchasing decisions of police force areas were seen as problematic, delaying integration of data across the police service as a whole. The lack of understanding of evidence in cybercrime cases by lawyers (including judges) and jurors was a cause for concern. This recommendation was no doubt wholly unsurprising to the Home Office (including the Police Information Technology Organization – PITO) and informed others.

That thinking on crime reduction be incorporated into the mainstream of central government and business decision-making. Similarly, ongoing programmes to encourage 'horizon scanning' to identify and prepare for future threats should be established. This recommendation reflects the Felson perspective on crime. Ways in which it could be concretized include the application to central government of the obligation imposed on local government by s. 17 of the Crime and Disorder Act 1998 to consider the crime consequences of any decision taken. The relevance of this recommendation to science and technology development is indirect but important. There is good reason for obligations placed on local government to be placed on central government also, if only on a 'what's sauce for the goose is sauce for the gander' basis. However, there are practical reasons for s. 17 to apply to national government. The first is to remove anomalies. For example, as in the Aquarium Investments case in Brighton (see Moss 2005), planning applications rejected locally on s. 17 grounds are appealable to the Planning Inspectorate, an arm of central government. Thus (as in the Aquarium Investments case) a decision properly taken locally on s. 17 grounds will be overturned centrally because s. 17 considerations do not apply – the two-act charade all taking place at public expense. As for science and technology, making s. 17 nationally applicable would require crime thinking to be incorporated into decisions on science strategy no less than elsewhere. Under Freedom of Information Act provisions, adherence to this requirement would become transparent (or at least more transparent than it is now).

That a programme be developed to address crime at all stages of a product's life-cycle. This recommendation incorporates the following sub-elements:

1. Identifying the roles of manufacturers, retailers and customers in developing secure products.
2. A voluntary standards system within manufacturing which would show that the criminogenic capacity of a product had been addressed to diminish criminal misuse and stealability.
3. The contribution of the retailer, particularly the impact on crime of e-commerce and home delivery of products purchased electronically.
4. How to encourage a climate of demand for secure products amongst consumers.
5. An annual award for new products which have been designed with crime reduction in mind.

It would be untrue to say that this process is substantially advanced at the time of writing. The annual competitions of the Royal Society of Arts for crime-reductive design give instances of where novel engineering solutions to diverse crime problems (from bicycle theft to ATM robberies) may be found. There is ongoing research funded by the European Commission about the crime-proofing of products and services (Project MARC), and there are evaluations demonstrating the crime-reductive effects of building design (see Armitage 2000), but there is no wholesale movement towards engineering and science solutions to crime problems. This will have to await action on Recommendation 4, above, which is the most fundamental of the recommendations.

The Police Scientific Development Branch (PSDB)

Of all the current science facilities within the Home Office, PSDB comes closest to a pan-science approach (see PSDB 2004a, 2004b). Whilst proclaiming that it is 'not a research institute', visitors are likely to conclude that it is indeed a research institute doing high-quality applied and operational research across a range of topics from the establishment of standards of stab resistance for police body armour through devising the Battenburg design to maximize the visibility of police vehicles, to the use of Raman spectroscopy in explosive and drug detection. A major strand of its work currently concerns the tracking of people and substances, which is applied in contexts as varied as primary schools and political party conferences (although perhaps the contrast is not so extreme, after all).

A particular strength of PSDB is ingenuity in choosing from a range of technologies to address particular problems in novel ways. For example, it addressed the problem of prison suicides by the development of a life signs monitoring system. This locates low-power microwave sensors in the cells of prisoners deemed at risk of suicide, and monitors movement. If all movement ceases (or presumably if there are periods of frenzied activity) prison officers are alerted. One project is noteworthy in that it takes criminological research showing that the probability of burglary is very high in the wake of prior burglary to design alarm technology which can be conveniently

installed for short periods after a burglary (Griffiths *et al.* 1998; PSDB 2004c).

There is something very endearing about an outfit where people with PhDs in theoretical physics and expertise on black holes are working on tracking technologies. Their breadth of imagination is admirable and refreshing. However, PSDB work is instigated primarily by demands from the police service. The question inevitably presents itself as to whether there are modes of thought within science which would be applicable to crime reduction if they were brought to bear. Put another way, is there science support that police and local Crime and Disorder Partnerships would like to have but do not know that they could have?

To rehearse the argument so far, Home Office science strategy has, acknowledging some outliers particularly in the work of PSDB, concentrated on a limited number of topics, notably unique identifiability and telecommunications. There have been recent signs of a broader conception of science relevance, evident in both the Foresight Crime Panel recommendations and the Engineering and Physical Science Research Council's (EPSRC) initiative which flowed from that. In the next section, the EPSRC initiative will be outlined, together with the work of the Jill Dando Institute of Crime Science at University College London. Thereafter the idea of trickle down from military applications will be introduced. In the concluding section, the notion of discipline blind spots will be mooted, with some suggestions about how these might be eradicated.

The EPSRC Initiative

Following the recommendation of the Foresight Crime Panel, the Engineering and Physical Science Research Council (EPSRC) launched its 'Think Crime' initiative on 1 November 2002.¹¹ Table 7.33 summarizes the general areas of projects funded in the first two rounds of the initiative, and it will be seen once more that projects addressing preventive (rather than forensic or offender tracking) technologies are in the minority. Projects within each of the categories are exciting in their own terms, including the first attempt at using nanotechnology to identify the presence of illicit substances and the development of an algorithm to aid classification of deaths as murder, suicide or accident.

None the less, the balance of work substantially reflects the activity suggested by the police science strategy document discussed earlier. The quality and

Table 7.3 Projects and networks funded in the first two rounds of the EPSRC crime initiative

	First round	Second round
Forensics	8	7
Surveillance/tracking	6	5
Preventive	3	3

commercial possibilities of the projects are substantial. Even though, in terms of general category, they tread well worn paths, they more than justify the initiative of EPSRC. Parallel initiatives by the other research councils would be welcome.¹²

Glass ceilings and crime science

The reader who has accepted the chapter's argument to this point will be persuaded that science enters the lists against crime primarily in the form of:

1. forensic analysis (wherein evidence is generated which uniquely identifies and locates an individual, object or substance); and
2. telecommunications (wherein relevant information is collected, stored, processed and analysed in ways which aid criminal justice).

There is an overlap between these areas (one may instance CCTV and vehicle tracking). Less developed in the public arena at least is science deployed in making the crime event less likely to occur. There are three questions which can be posed about this state of affairs, all of which imply 'glass ceilings' of different kinds. The glass ceiling is the concept coined to reflect invisible limits on achievement. The first question concerns whether there already exist science solutions which have not been commercially realized. The second is whether there is effort to prevent crime events which impact upon business or state security of a scale which makes science applied to crime reduction look relatively feeble. The third is whether the disciplines contributing to crime reduction are the 'natural' ones, or whether there are others which could make a contribution, which have not yet been considered.

One person's solution in another person's pocket

It seems clear to the point of self-evident that some useful crime-reductive products remain commercially unrealized. None of the winning entries to the annual Royal Society of Arts crime-reductive design competition has yet been taken up commercially. Many ingenious devices produced by students of the Royal St Martins School of Design remain without a commercial developer. The Stealthguard research team within BT in the late 1990s, which explored the development of location-aware electronic products, did not translate into commercial reality. The instances could be multiplied many times. The obstacles include the selling of products by association with criminal victimisation, and the sometimes limited scale of anticipated demand. Discussion of tax and other inducements in the translation of science ideas into crime-reductive products seems urgently necessary.

If it matters to a nation or a business, science will be deployed to prevent it

During the first Gulf War, amongst the most arresting images were those of Cruise missiles lumbering above a street in Baghdad towards its target. With

that image, the potential of global positioning system (GPS) became clear. Yet ten years later, this had not surfaced in the continuous tracking of tagged offenders. Multinational companies have emerged to address particular crime forms which are mission critical for companies and states. De La Rue, for example, is 'a global company employing over 6,600 people across 31 countries, is the world's largest commercial security printer and papermaker, involved in the production of over 150 national currencies and a wide range of security documents'.¹³ The effort expended to control counterfeiting is immense because of its potential to compromise national economies. Conversations with those responsible for military aircraft and nuclear power stations make clear the sophistication of perimeter security in those contexts. Entering into the Google search engine the keywords 'Critical Infrastructure Assurance' yields 259,000 results, perhaps a record for a phrase not involving sex or popular culture. In brief, there is a shadowland of crime-reductive effort expended in national and commercial interests. Although difficult to be precise, there seems to be some trickle down of preventive technologies from such applications to the public domain, and this appears to be the result of personal contacts and spin-offs from military and commercial contracts. The fact of a dual standard can be instanced by reference to global positioning technologies. The levels of GPS performance the USA allows to civil agencies are fully documented (US Department of Defense 2001).

Respecting confidences makes this section difficult to write. Put succinctly, there is a range of security measures deployed in national and commercial interests. It would certainly be helpful if more attention could be paid to identifying techniques which are obsolete in military and commercial terms which would none the less offer an improvement on more generally available crime reduction technology. The first step in achieving this is recognizing it and creating a national government awareness of the issue. The present situation was expressed to the writer as follows: 'the transit of technology from more secure to less secure applications is most often controlled by those who currently use the technology.'

The disciplines which have traditionally contributed to an understanding of crime have been only a subset of those which could be brought to bear. This insight led to the establishment of the Jill Dando Institute for Crime Science at University College London (hereinafter JDI). Considering crime as being the result of the supply of opportunities and the demand for opportunities (otherwise thought of as criminal inclination, transient or enduring), the work of the institute has primarily centred upon the supply of opportunities, and its control.¹⁴ However, its mission statement encompasses both: 'Our mission is to change crime policy and practice. The Institute plays a pivotal role in bringing together politicians, scientists, designers and those in the front line of fighting crime to examine patterns in crime, and to find practical methods to disrupt these patterns.' The work of JDI will be mentioned later in the attempted rapprochement of quantitative criminology and epidemiology.

As an article of faith, all science disciplines may contribute to the mission. This was put to the test in a simple way (see Giles 2003) where papers from diverse science research groups within University College London were submitted for identification of their science relevance. These were deliberately

challenging (for example one was about temperature variation in the Gulf Stream) but in the writer's view, plausible parallels were drawn in each case. Ekblom (2004) also takes this as a starting point, seeking 'to alert, motivate and empower the wider science and engineering community to act as "scouts" in this task – to systematically "think crime"'. Ekblom's (2004) developments of his tests for crime risks and crime prevention opportunities are too extensive to be detailed here, but provide an elegant scout's handbook for those in the science and technology community wishing to accept his challenge.

For present purposes, two examples must suffice. The first is ecology, the second behaviour genetics (and its close relative evolutionary psychology). Ecology is interesting in that its central components are similar to the elements of Marcus Felson's depiction of crime, with motivated offender (predator), suitable victim (prey) and capable guardian (predator on predator) operating in a habitat where the balance of factors makes for ecological niches for crime. Shifts in crime rates can be conceptualized as co-evolutionary struggles. Ekblom (1999) brilliantly outlines some of the possible implications. He writes

Crime prevention faces a perpetual struggle to keep up with changing opportunities for crime and adaptable offenders. To avoid obsolescence, it has to become adaptive itself. The task of keeping prevention up to date resembles other 'evolutionary struggles' such as biological co-evolution between predator and prey (eg continually sharper teeth versus continually tougher hide) (p. 27).

The specific lessons drawn by Ekblom *include* the following (the Ekblom piece should be read in the original for its dazzling variety of implications):

1. The incorporation into crime reduction of engineering principles from struggles in nature. One example is the use of predetermined fracture points (as in an lizard's detachable tail). This principle was (after Ekblom wrote) incorporated into one entry into the Royal Society of Arts annual student competition on designing out crime, where mobile phones were attached to one's belt or bag in such a way that, if snatched, the most valuable part of the phone, the chip, remained on the lanyard rather than was taken. A variant of the method comes with cases used to prevent loss in cash theft, where the act of detaching the case from its carrier sprays a permanent die on the cash, rendering it worthless. Another example which postdates the Ekblom paper is the product 'Smokecloak'¹⁵ which sprays non-toxic smoke into secure environments when under attack, as the squid sprays ink to thwart predators.
2. Threats should be perceived distally. It is, for example, contended that animals did not die in large numbers in the East Asian tsunami which claimed (according to the estimate at the time of writing) 200,000 human lives.¹⁶ 'Sri Lankan wildlife officials have said the giant waves that killed over 24,000 people along the Indian Ocean island's coast seemingly missed wild beasts, with no dead animals found. "No elephants are dead, not even a dead hare or rabbit. I think animals can sense disaster. They have a sixth

sense. They know when things are happening,” H.D. Ratnayake, deputy director of Sri Lanka’s Wildlife Department, said.’ The implications here are for the development of remote-sensing technologies.

3. Things should be varied. Monoculture (whether of software, buildings or products) makes for vulnerability. The virtual ubiquity of the Microsoft Windows operating system makes its users prone to attack. This was instanced by one respondent in a survey of burglars who specialized in petrol stations, where uniformity of design relieved him of the responsibility for finding anew at each station where valuable goods were kept and how protected (see Ashton *et al.* 1998).
4. To be adaptable, things need to be simple. ‘Phylogenetic constraint’ occurs where an evolved system becomes so complicated that radical redesign is impossible (see Raup 1993).

Ecology has attracted other prevention-minded criminologists (see, for example, Eck and Weisburd 1995), but that interest has not to the writer’s knowledge proceeded to the point where the algorithmic nature of evolution (see Dennett 1995; Morin 1999) is taken advantage of in modelling crime trends and types. An early sally in this direction might be to adapt some of the common evolution simulation software (such as *Evolution Lab*) to crime simulation purposes.¹⁷

The second science instanced is behaviour genetics. Its relevance to crime reduction may be primarily via the demand for opportunities route (see Walsh and Ellis 2003). In her admirable, unfashionable classic *The Nurture Assumption*, Judith Rich Harris (1998) contends that the contributions which parents make to their children’s development primarily comprise their genes and where they decide to set up home. She points out that in the socialization literature, the effects of parenting styles are confounded with those of shared genes. She reviews the literature on the relationship between parent characteristics and child characteristics and demonstrates that either the same characteristics must have different and largely unpredictable effects on children, or that those influences are largely illusory. Is poor parenting a risk factor in a child’s development, or do parents tending to (for example) impulsivity transmit that attribute through the conventional genetic means? Familial inheritance is always both the result of genetic endowment and environment, but environments are made, and are often correlated with the dispositions of those who inhabit them. The implications of Rich Harris’s work are profound. They should be no surprise to those familiar with the earlier literature on criminality and biology (see, for example, Shah and Roth 1974; Mednick and Christiansen 1977). The latter authors demonstrated that criminality in the *biological* parent is reflected in a higher prevalence of criminality in the child, whatever the criminal record status of the *adoptive* parent. The importance of genetic factors is lent support by the work of Terrie Moffitt and her collaborators (see Moffitt 1993, 1997, 2003) whose distinction of adolescent-limited and life-course persistent offenders casts the latter as predisposed as a result of inherited and/or early acquired neuropsychological deficit. Of particular current interest is the gene variant MOAO which lowers the activity of the enzyme monoamine oxidase

A and which seems implicated in violence. This relationship is stronger amongst maltreated children (see Caspi *et al.* 2002). Of course, reflecting Rich Harris's insights, it is not necessarily the case that maltreatment activates the propensity to violence. Equally plausible is the notion that MOAO and other as yet to be identified violence-relevant genes drive both parental violence (in the form of maltreatment) and child aggression. In path terms, the message is simply that one ignores at one's peril genetic or other early factors disposing to preferences. Equally, care in interpretation must be taken, given the saga of the XYY chromosome complement and its link to criminality (see Fox 1971).

Before leaving the notion of intrinsic path preferences, mention should be made of the work of Donohue and Leavitt (2000, 2003). They persuasively show rates of crime to be inversely related to earlier abortion rates, the time lag reflecting time to age of maximum criminality. The suggestion is thus that attributes (for example, of impulsivity) which yield unwanted pregnancies, possibly genetically shared with the resulting foetus, combining with parental styles reflecting both the same impulsivity which led to the pregnancy and possible resentment felt towards the resulting child, results in a greater likelihood of criminal involvement. The Leavitt and Donohue work does not disentangle the skein of causal routes. Still less does it argue for abortion rather than less troubling modes of fertility control. However it does suggest that an unwanted pregnancy may be, for whatever reasons, a marker for future criminality. Any of the plausible causal routes would be closed off by the avoidance of such pregnancies. This way does not lie eugenics. Phenylketonuria is a disorder of genetic origin whose expression is controlled by environmental means.¹⁸ What it must mean is that the deep-seated and understandable reluctance to admit genetic factors to a contributory role in the demand for criminal opportunities has to be put aside. The physiology of nutrition could also have been used to illustrate a neglected discipline. Whilst the current fad is for herbal tea in reducing prison violence¹⁹ there is a much more substantial research literature linking diet and criminality which merits re-examination. (See Schoenthaler *et al.* (1997) for an example of a pristine double-blind trial demonstrating the efficacy of diet supplementation in reducing prison violence and anti-social behaviour.

The final example of neglected science is presented with the most diffidence. It concerns evolutionary psychology. This is concerned with behaviours which can plausibly be regarded as adaptive, favouring the survival of one's own offspring (more relevantly one's own genes) over those of others. This has both obvious and more arcane forms of expression. Straightforwardly, it accounts for the much higher incidence of child abuse by carers who are not biologically related to the child victim, the ratio of 100:1 being mooted. Daly and Wilson's (1998) book *The Truth about Cinderella* makes the point fully and disarmingly (one would say entertainingly were the topic they treat not so painful).

The more subtle criminal pathway choices derive from the notion of discounting. Organisms discount the future when they value imminent goods over future goods. If you aren't going to be around tomorrow, you prefer even risky rewards today. Worker bees assume more dangerous foraging activities as their wings wear and in response to life-truncating infection (Woyciechowski and Kozlowski 1998). The notion that offenders find deferral of gratification

difficult has a very long history (see, for example, Herrnstein's (1983) review). The phenomenon is now known as time discounting. Wilson and Daly (1997), noting that the poor, the young and the criminal discount the future steeply, contend that is what we should expect, being a rational response to information indicating a diminished probability of survival or other obstacles to reproductive success. Risk-taking is rational when the expected benefits of safer courses of action are negligible. Thus early and aggressive sexual behaviour is linked with time discounting.

Readers with long memories will recall that this section is about the second of two 'glass ceilings' which seek to illustrate that there is a range of science contributions which are not currently being mainstreamed in the crime reduction enterprise. If the reader has gone along with the argument to this point, he or she will accept that crime reduction would be well served by facilitating trickle-down of military and commercial applications, and by having recourse to a wider range of science disciplines.

The farmer and the cowhand should be friends?

In the musical *Oklahoma!*, harmony between those making different uses of the same land is invoked in the rousing song of that title. In this last section of the chapter, the advantages which accrue from collaboration between the hard sciences and criminology will be sampled. This has already been instanced by the development of intruder alarms suitable for temporary deployment after burglary (Griffiths *et al.* 1998, PSDB 2004c). This is done by providing brief accounts of two projects which illustrate the benefits to be gained.

There now exists a method of anticipating the distribution of local crime in the short term. Hotspotting is close to ubiquitous in the work of police analysts, but all extant methods are essentially retrospective, using the historical pattern of crime as the benchmark. The method of prospective mapping significantly outperforms the most sophisticated historical method available. This method is currently under trial in the English East Midlands region. It is not a finished product, being capable of refinement in terms of calculation and optimizing police patrol patterns in the light of the information it conveys. However it is an exciting innovation. Its discipline origins should be explained. Traditional quantitative criminology established that a recently victimized home or person was more likely to suffer repetition of the crime in the short term (see Farrell and Pease 2001). Application of techniques from epidemiology developed to study contagious disease showed that risk of victimization spread spatially (Townsend *et al.* 2000; Townsend 2001). Putting these data together allowed the calculation of risk surfaces (Bowers and Johnson 2004). In short, it allowed the use of the crime event's predictive power. Incorporating this with mapping expertise yielded the technique under discussion (Bowers *et al.* 2004). Thus the technique is a result of a marriage of geography, epidemiology and criminology.

The second direction of work concerns a consideration of how DNA and fingerprints might be used in a novel way. Historically the informing spirit of these techniques is the striving for unique identification of individuals. As

this chapter has sought to show, unique identifiability remains a goal of much police science strategy. However, that is not the only way of thinking about DNA and allied technologies. Indeed, the notion that a day will dawn where all active offenders are to be found on the DNA database is naïve. This is because of the high churn rate in active offending, with many offenders desisting, and many neophytes starting a criminal career. At a rough guess, no more than two thirds of active offenders will be found on the database, and no more than two thirds of those on the database will be active offenders. A different way of thinking about these technologies is in terms of restriction of the suspect pool. This approach is already employed in the investigation of major crime (see Wilson *et al.* 2003 for the relevant statistics). Criminologists will be familiar with the Farrington and Lambert (2000) approach to offender profiling. They identify those personal characteristics of offenders about which witnesses are least often mistaken, and show that small suspect pools result if the presenting combination of such attributes in witness statements is considered. This approach can be equally applied to genetic markers. Thus, one can tell something about the phenotype from appropriately directed genetic assay. Put simply, one can tell something about how someone looks from particular genetic markers. For common characteristics, this can be done with accuracy for eye colour and skin tone/ethnicity, with hair colour also being the subject of research (McDonald and Foy 2004).²⁰ This work could reasonably be put alongside other work on pathologies, so that (for example) rare tooth anomalies (Tabata 1998) or shortness of stature (Mullis *et al.* 1991) could be candidates for inclusion. Considering enough rare pathologies should in principle allow a huge reduction in uncertainty, it would of course not matter for this approach whether the person concerned was on the national DNA database. A similar logic applies for partial fingerprints. Combining witness statements with DNA assay and other sources of evidence extends the scope of the Farrington and Lambert perspective on offender profiling.

Endnote

The message of these two projects, along with others, sounds hackneyed. It is that the insights afforded by considering the contributing disciplines, and combining them in institutions and research groups which contain diverse crime-relevant expertise, are valuable and potentially of enormous practical importance. The broadening of the police science strategy, the work of the Foresight group and the initiatives which it (or the Zeitgeist) spawned is welcome and represents movement in the desired direction. However, everywhere silos are strong. That, after all, is why silos are used to contain things. Watching the Jill Dando Institute and the Home Office struggling against silo organization of science disciplines makes their strength clear. The ESRC Ideas Factory,²¹ the Jill Dando Institute and other silo-averse enterprises should be strengthened. Other research councils should follow the ESRC lead. Exchange arrangements between scientists with crime-relevant expertise should be multiplied. The Exchequer should consider fiscal means of facilitating the bringing to market of science-inspired crime-reductive

products. The European Commission could, along with its more arcane crime-funding initiatives, develop the pan-science vision. Even if the cowhand and the farmer don't get along, the forensic entomologist (see Catts and Goff 1992) and the criminologist should try.

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Selected further reading

Melissa Smith and Nick Tilley's book of readings, *Crime Science: New Approaches to Preventing and Detecting Crime* (2004), shows how researchers at the Jill Dando Institute, mostly social scientists, are striving to integrate science effort for the purposes of crime reduction. This could profitably be read alongside Joe Nickell and John F. Fischer's book, *Crime Science: Methods of Forensic Detection* (1999), which provides a traditional, detection-oriented view of crime science. Paul Ekblom's (1999) lengthy piece characterizing offending and its prevention as an evolutionary struggle (*Studies in Crime Prevention* 8) provides an illustration of a conceptual carry-over from zoology to criminology. Integrative attempts are increasing in number and sophistication. Amongst the websites on which such material is likely to appear are those of the Jill Dando Institute (www.jdi.ucl.ac.uk), the Engineering and Physical Science Research Council (www.epsrc.ac.uk/) and the Home Office's Police Scientific Development Branch (www.homeoffice.gov.uk/crimpol/police/scidev). When the PSDB changes its name, searchers on that site will be redirected appropriately.

Notes

1. In the weeks before writing this, these aims were complemented and will in due course be replaced by 'objectives', of which the overarching crime-related one is to ensure that 'people are and feel more secure in their homes and daily lives'.
2. <http://www.homeoffice.gov.uk/inside/aims/index.html>, accessed 20 January 2005.
3. It is of interest that local authorities are mentioned as such, and that local Crime and Disorder Reduction Partnerships remain invisible. Furthermore, the local authority links to the police are mediated through the police authority, which is foreign to the spirit of the Crime and Disorder Act 1998.
4. In passing, the relevance of detection to the prevention of the (next) crime is acknowledged. Indeed the writer has elsewhere argued that instead of the traditional duality of crime prevention and detection, there is really only one, prevention, to be achieved by deflection or detection (Pease 2001).
5. By asserting that moderate access makes for stealability, the writer is more dogmatic than Felson. Rare objects have limited saleability by the thief, and universally owned items are not worth stealing.
6. See David and Sakurai (2003) for a discussion of the sub-problem of cyber-terrorism.

7. See the website of the Information Assurance Advisory Council which 'addresses the challenges of information infrastructure protection (<http://www.iaac.org.uk/>, accessed 31 January 2005).
8. <http://www.nhtcu.org/> (accessed 31 January 2005).
9. Or as being an early indication of a Zeitgeist which spawned these developments.
10. See the Association for Payment Clearing Services (APACS) at <http://www.apacs.org.uk> (accessed 31 January 2005).
11. <http://www.epsrc.ac.uk/default.htm> (accessed 27 January 2005).
12. An interesting marginal activity of EPSRC is its 'Ideas Factory', which is 'designed to combine new ways of generating research directions with new approaches to peer review'.
13. <http://www.delarue.com/> (accessed 28 January 2005).
14. <http://www.jdi.ucl.ac.uk/> (accessed 28 January 2005).
15. <http://www.smokecloak.com/general/msshhistory.asp> (accessed 28 January 2005).
16. <http://www.cnn.com/2004/TECH/science/12/30/quake.animals.reut/> (accessed 28 January 2005).
17. <http://www.biologyinmotion.com/evol/> (accessed 29 January 2005).
18. <http://www.geneclinics.org/profiles/pku/> (accessed 29 January 2005).
19. <http://www.ukcjweblog.org.uk/2005/01/26.html#a1942> (accessed 29 January 2005).
20. This work resulted from discussion at the Foresight Crime Panel.
21. <http://www.epsrc.ac.uk/ResearchFunding/Programmes/Cross-EPSRCActivities/IDEASFactory/default.htm> (accessed 30 January 2005).

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