

Confidential

Omagh Bombing Inquiry (OBI)

Scientific Report 1

**Background/Overview of the
Scientific Tests & Techniques
Available in 1997/98**

January 2026

**& including responses to
CP observations
April 2026**

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Executive Summary

This report briefly explores the nature of forensic science and the richness and variety of types of science it encompasses. This reflects the fact that any kind of physical trace can theoretically provide evidence to link an offender with their crime, or help to exonerate the wrongly accused.

It looks at the role of forensic science in criminal investigations, and how forensic science has changed since the time of the Omagh Bombing. Four main areas of change have been selected for special mention including:

- **Digital forensics** which, as a forensic discipline, has grown exponentially since the late 1990s, reflecting the extent to which we all now rely on digital devices, the information they can access, and what they record about our own activities. Challenges include keeping pace with further technological change to stay ahead of the criminal, and how to manage burgeoning digital forensics caseloads.
- **DNA profiling** which is enabling scientists to obtain profiles from much smaller amounts of DNA - which no longer need to be visible to the naked eye, are much more discriminating – with a full profile occurring in less than 1 in 1bn people in the general population, and can provide additional information – for instance about male-only DNA including in mixtures of male/female DNA.
- **Chemical analysis** – such as of drugs, and drug residues (in body samples) and explosives which, again, enables much smaller amounts of material to be analysed, producing more detailed results which discriminate more finely between one sample and another and often instantly identify the chemical compound(s) within a sample, and all more quickly and cost effectively than hitherto.
- **A more scientific and objective approach to evaluation** – of both forensic testing opportunities, and the evidence that emerges from them. This helps to make forensic science more robust, transparent, logical and balanced, and therefore more fit for purpose.

Focusing next on aspects of forensic science of specific relevance to terrorist offences involving bombs, the report considers the sorts of tests and techniques that were used by forensic analytical chemists at the relevant time to identify and compare **Explosive substances**, highlighting second order detail which could provide additional information. The report then describes the essential components of **Explosive devices** and how they work, and the links they can provide with those who make and deploy them and, potentially, links with other related incidents. It also outlines the additional challenges faced by bomb scene investigators to put both their own, and the subsequent laboratory work into proper perspective.

Following this, two of the most common types of forensic traces by which offenders can potentially be personally identified are considered – namely fingerprints and DNA. In relation to **Fingerprints**, the physical and chemical enhancement techniques available in the late 1990s for locating and visualizing prints are outlined, the way in which fingerprints were analysed and compared, and the databases available to assist in identifying the source of unknown fingerprints. The concept of cognitive bias is briefly introduced here because of subsequent evidence that this could have affected interpretations of fingerprint (and other forensic) comparisons made at the relevant time.

DNA profiling was first developed in the mid-1980s and has advanced enormously in the intervening years. The report briefly explains what DNA profiling involves, the history of its development and what it was, and was not capable of at the time of the Omagh Bombing. The risks of contamination with the more sensitive modern techniques are highlighted. This was not such an issue at the relevant time but is mentioned here because it can affect re-investigations of original items using modern techniques.

Then, broadening the scope, the report examines other key forms of forensic evidence, namely textile fibres, and marks and chemical traces. These can provide, if not direct, then very useful associative evidence. **Textile fibres** are everywhere – in our clothes, in the vehicles we drive, in our homes and those of our friends, family and work mates. We constantly leave behind our own fibres, and pick up fibres from others as we go about our daily business. These tiny, transferred fibre fragments can then provide physical evidence of where we have been, and what we have done. The report explores how forensic scientists collect, examine and compare fibres, and how they work out what finding them, or conversely not finding them, is likely to mean in a given set of circumstances. Risks of unwitting contamination involving such tiny traces – mostly invisible to the naked eye, and steps taken to avoid this, are briefly addressed.

A wide variety of **Marks** are of interest to forensic scientists – such as tool, shoe, tyre and manufacturing marks, and other kinds of **Chemical (as opposed to biological) traces** with which they may be associated. Such traces could include, for example, tiny shards of glass and flakes of paint associated with a tool used in breaking and entering a building. The tests and techniques associated with these sorts of examinations are outlined and when overlaps with those used to explore other forms of forensic evidence become clear.

The report then considers the part that handwriting, and the many other aspects of **Documents analysis** and comparison can play in revealing who might have written, altered or forged a document in connection with criminal activity. Forensic evidence of this kind can be relevant in a wide variety of different kinds of cases including terrorist offences.

Finally, the report turns to more general matters such as which organisations were providing forensic science services in the UK at the relevant time. While the Forensic Science Service (FSS) was dominant in England and Wales, private providers were beginning to emerge in what was becoming a forensic market. Scotland and Northern Ireland were served by their own laboratories – run by the police, and the Northern Ireland Office respectively. In addition, a number of smaller firms and individuals were providing specialist, and/or second opinion services.

The role of the main laboratories was mainly to provide the police with scientific services covering everything from crime scene to court room. Individual lead scientists would be responsible for translating a senior police investigator's requirements into a scientific strategy – to be carried out at the laboratory, and to adjust this as necessary depending on emerging test results and new information gathered by the police investigation team.

Information accessed to date, does not allow for precise comparisons of standards and approach between laboratories in Great Britain and Northern Ireland at the relevant time. But all the evidence suggests that they were being run along roughly similar lines, were equipped with the same sorts of scientific instrumentation and followed the same types of protocols and, if there had been any marked disparities between them, this should have been picked up through inter-laboratory proficiency exercises, and/or independent experts reviewing individual scientist's work on behalf of the defence.

The report concludes by summarising some of the main points to emerge in a concluding summary.

1. Introduction

- 1.1 This report provides an overview of the sorts of tests and techniques commonly in use in forensic science laboratories in England and Wales, Scotland and Northern Ireland during the period 1 September 1997 to 15 August 1998 as they might relate to the original investigation of the Omagh Bombing, and previous incidents with which this bombing might potentially have been connected.
- 1.2 It has been compiled with the assistance of a team of highly qualified and experienced forensic scientists/scene investigators in a range of relevant forensic science disciplines as follows:
- **Explosive Substances** - Dr Keith Norman
 - **Explosive Devices** - Christopher Hester
 - **Fingerprints** - Kevin Kershaw
 - **DNA** - Dr Philip Avenell
 - **Textile Fibres** - Roger Robson
 - **Marks and Traces** - Dr Sarah Jacob
 - **Questioned Documents** - Melanie Pugh
- 1.3 They have been supplied with a large number of scanned documents (over 2,000 at the time of writing) variously ranging from witness statements to aspects of laboratory quality management, and investigation strategies to court rulings. Relevant information is scattered amongst these documents – reflecting the long and complex history of their compilation, extent of their previous interrogation, *and their arrangement within the digital database in which the scanned documents are housed*. To this extent, the scientists cannot be certain that they have located all pertinent references to matters raised by the Omagh Bombing Inquiry (OBI).
- 1.4 The report is structured around a series of questions posed by the OBI in their Letter of Instruction dated 1 August 2025. *(For ease of reference, numbering within the main body of this report reflects that in this Letter.)*
- 1.5 These questions start with a request for a general explanation about the nature of forensic science, its role in criminal investigations, and the extent to which it has changed between the late 1990s and now. These are addressed by the main author of this report, Professor Angela Gallop, whose long and varied career in forensic science dates back to 1974 - as described in summary form, and then in a full CV presented at **Annex A**.

1.6 Next, a series of more specific technical questions are addressed by each of the experts listed above in relation to their own specific forensic discipline. Again, summary CVs are provided in respect of each of them, with fuller versions included at **Annex A**. These requests/questions are as follows:

- a) Provide an overview of each test or technique that was available to the UK State during the period 1 September 1997 to 15 August 1998 for use in police investigations to assist the UK State in identifying those engaged in the planning and preparation of acts of terrorism, particularly involving the use of bombs
- b) How widely used or established were these tests and techniques at the time, and were there any limitations on their use?
- c) How was each test or technique used practically?
- d) What forensic material and, if applicable, in what quantity, was required for the test or technique to be reliably used?
- e) Were there any types of testing or technique that were believed to be unreliable at the time but which have subsequently proved to be reliable, and the converse,
- f) Were there any types of testing or techniques that were believed to be reliable at the time but have subsequently proved to be unreliable?

1.7 Moving on, the report then considers by whom and where forensic testing was carried out in Great Britain and Northern Ireland and, in general terms, the role of The Forensic Science Service (FSS), the Forensic Science Agency Northern Ireland (FSANI) - now Forensic Science Northern Ireland (FSNI), and private providers of forensic science services at the relevant time. It also explores whether there was any difference in the standards or approach to testing between Great Britain and Northern Ireland, as reflected, for example, in written guidance or codes of practice, and whether there was a Regulator for forensic science in post at the time. The report then addresses who was responsible for setting the forensic science strategy in a criminal investigation, and how and by whom this was kept under review before, finally, drawing all the various strands together by way of a concluding summary.

After completion, this report was circulated to the Core Participants who came back with various observations/requests for clarification or more detail. These were distilled by the Inquiry Legal Team into a number of matters¹ which have

¹ INQ041423

been addressed by the scientific team - whose responses appear in red at the appropriate places within the original text of the report.

2. Q2: Forensic Science

OBI-Q2a. What is forensic science?

2.1 Forensic science encompasses any of a wide range of physical traces that can be transferred to or from the offender during the commission of a crime, or otherwise used to link them with it, and later be used to provide evidence of a suspect's guilt or innocence. Such traces commonly include for instance fingerprints, tool, footwear and other kinds of marks, DNA in body fluids and tissues, textile fibres from clothing and soft furnishings, small fragments of materials used in buildings such as paint and glass, other chemical traces and, increasingly, digital data from mobile phones and CCTV cameras etc.

2.2 These traces can assist in implicating or, alternatively, eliminating suspects as potential offenders in criminal investigations by, for example:

- Helping to confirm whether or not a crime has been committed
- Suggesting the likely sequence of events at the crime scene and therefore where best to look for evidence of physical traces from the perpetrator(s)
- Identifying or eliminating suspects through comparison of such physical traces either directly with reference samples taken from them, or indirectly via a database on which results from such reference samples are stored
- Identifying something useful which may help to lead to the offender eg. amongst physical traces they may have left behind them at the crime scene, or whether their MO suggests a possible link with another case or cases, or says something about their type of occupation
- Indicating which of conflicting accounts of events is more likely to be true

Some forensic traces can last a very long time – several decades in the case of DNA when items stained with body fluid have been stored under the right environmental conditions, however others can perish very quickly in the wrong environments; some traces can be detected in such small quantity that they are not visible to the naked eye – such as tiny flakes of paint or shards of glass; other traces need to be physically or chemically 'enhanced' before they can be seen – such as latent fingerprints and footwear marks; some traces occur very commonly in the general environment while others are extremely rare. Textile

fibres are a good example of this with blue denim fibres, for example, being ubiquitous to the extent that they are often not considered worth searching for as a potential evidential link. This contrasts with, say, individual fibres from printed fabrics which can include a number of different specific colours. These will be much rarer and therefore much less likely to match other fibres in the fibre population at large just by chance, which will dramatically increase the potential evidential value of any such matches found.

- 2.3 But whatever the type of trace, there are two additional considerations that need to be explored before any trace can safely be regarded as any kind of evidence for a court to consider. The first of these relates to '*continuity*' or the demonstration of an unbroken chain of custody proving that the item or sample tested was precisely the same as the one originally recovered from the crime scene, victim, or suspect etc. The second consideration relates to '*integrity*' and the necessary assurance that there had been no realistic opportunity for the 'evidence' alternatively to have arisen as the result of some contamination event through deficiencies (either consciously or unconsciously) in its handling, storage or processing.
- 2.4 Thus, forensic science is not just the sum of a series of scientific tests, but also the scientific strategy behind them, and how this evolves during the course of an investigation. This strategy will dictate which items and samples - in some cases of many hundreds collected, will be examined, for what, and in what order, and then the careful assessment, interpretation and evaluation of the results in the specific context of the case at hand.
- 2.5 As to how long the scientific work is likely to take, some tests will take longer to perform than others reflecting, for example, technical complexities of finding potential evidence to test, the amount of material available, sophistication of the instrumentation involved, and the nature and extent of the workload within the laboratory at the time and competing priorities within this.
- 2.6 In most cases, and especially larger ones, a team of scientists will be required to cover the range of different activities and scientific disciplines likely to be involved. This team has to work closely together to ensure that examinations are conducted in a properly co-ordinated and appropriate manner to help ensure that available evidence is found, and not lost, damaged or compromised.

OBI-Q2b. What is the role of forensic science in criminal investigations?

Forensic science is regarded as the cornerstone of any major police investigation because it is capable of providing a speedy, effective and independent steer as to the involvement or otherwise of potential suspects. To

this extent, and except in relatively straightforward investigations where the identity of the offender is immediately obvious, it will play a pivotal role² right from the start in any Senior Investigating Officer's (SIOs) evolving strategy for solving the crime and their constantly updated policy document in which this is recorded.

- 2.7 At the relevant time and depending on the nature and severity of the crime, one or more forensic scientists might have been called to attend the crime scene. There they would have been briefed by the SIO and then have worked closely with the police scenes of crime team there to support the SIO in the direction of forensic science strategy at the scene. This would include the senior scenes of crime officer (senior SOCO) or crime scene manager (CSM) – responsible for managing all aspects of the scene examination according to the strategy agreed with the SIO, other SOCOs – the collectors of evidence and gatherers of information, fingerprint experts who focused almost entirely on finger (and palm) prints, photographers – to record the scene, and an exhibits officer to keep the documentary record of all items seized and samples taken in the case. *PSNI have asserted that, in 1998, they had not adopted the role of Crime Scene Manager for police officers. Rather, a Lead Scientist may have undertaken this role, supporting the SIO in relation to the direction of forensic science strategy at the scene.*³
- 2.8 The scientists' role would focus on interpreting any evidence and patterns of evidence as to what had gone on at the crime scene, and advising about which items and samples to collect for further, laboratory-based investigation and how best to go about this to maximise evidence potential. They might also have been joined at the scene by an external specialist such as a pathologist and, in which case, they might then go on to attend post-mortem examinations of victims where further items and samples would have been taken. All of these items and samples would have been packaged, sealed and labelled, and documented in an exhibits log or register, and then sent for appropriate storage until and if required to be taken to the laboratory for detailed examination.
- 2.9 Bomb scenes presented a range of additional, significant challenges to those tasked with investigating the incident. There might have been **unconsumed explosives within the scene or secondary/booby trap devices** which have been placed specifically to target first responders or the investigation team. **Structural damage** caused directly by the explosion or secondary collapse could seriously impede access to the scene or prevent any meaningful work within it. It might have been necessary for structural engineers to assess the

² *Murder Investigation Manual. ACPO Crime Committee Published September 1998 (pages 41, 129), and in CD-ROM March 1999* INQ038310

³ INQ041423

damage and remedial engineering solutions put in place to limit further collapse during any investigative work. Bomb scenes could result in **copious debris fields**, all of which must be physically recovered and then examined in minute detail to reveal the smallest of clues. This work was not only demanding to the body but also the mind. In addition to the debris, in the case of fatal bombings, there is the issue of **human remains and body parts** which needed to be recovered with sensitivity. The physiological risk to those working in fatal bomb scenes should not be underestimated nor should the short or long-term mental toll.

- 2.10 Right from the start the SIO would have had ultimate responsibility for the investigative strategy in a case, and this would include the use of forensic science. Following the scene visit, the SIO would inevitably hold an early strategy meeting with the lead forensic scientist, the scientific support manager (SSM) for the Force - who controlled the forensic budget, and heads of some other police support teams – including relating to the crime scene, and together they would construct a forensic science strategy. Also present perhaps would be a representative from the force intelligence unit exploring possible links with similar crimes and known offenders living in the neighbourhood. In the light of the information which emerged from this, the SIO would make decisions about lines of enquiry to be pursued, priority items and samples for examination, and criteria to be used for eliminating suspects.
- 2.11 From then on, the scientists would provide the SIO and their investigation team with frequent updates of results of their scientific examinations, and these would be discussed at further regular meetings between them and the forensic science strategy updated. At the same time the SIO would be juggling information from other sources involved in gathering intelligence through house-to-house enquiries, witnesses' interviews, and in response to press releases and so on. All this information would be reflected in the SIO's evolving investigation strategy recorded in their written policy document and, in large cases, in-putted onto a computerised database (HOLMES) to facilitate the mining, retrieval and cross-referencing of information.
- 2.12 In the mid-to-late 1990s, murder investigation was gradually being standardised and professionalised. For example, there had been the adoption of standardised major incident room procedures, computerisation of investigation records, and development of a scientific advisor role in response to the 1981 report by Her Majesty's Inspector of Constabulary, Sir Lawrence Byford, on The Yorkshire Ripper Case⁴. Guidelines for good practice for scientific support unit managers were issued in a joint report by the Association of Chief Police Officers (ACPO) and the Forensic Science Service (FSS) in

⁴ 1981 report by Her Majesty's Inspector of Constabulary, Sir Lawrence Byford, on The Yorkshire Ripper Case (pages 156, 157) INQ038313

1995 entitled 'Using Forensic Science Effectively'⁵. This was then taken a step further in September 1998 with the publication of the Murder Investigation Manual by the ACPO Crime Committee⁶ which, for the first time, provided written advice and guidance to SIOs including a section on forensic awareness.

- 2.13 As the investigation broadened, forensic scientists might be required to visit and examine other premises (ancillary scenes) including the homes, work places and vehicles etc of emerging suspects, and from which more items and samples would be taken and on which more detailed laboratory examinations and analyses might be commissioned.
- 2.14 While scientists might have provided one or more interim reports on their emerging findings during the course of an investigation, if they found any evidence of links with a suspected offender, they would then have been required to summarise this in a formal witness statement. This statement would have set out the scientist's qualifications and experience to do the work, what they had been instructed to do, what they found, and what they thought it meant in the specific context of the case at hand including any further researches they might have made. If there were a subsequent court hearing, they might have been required to give oral evidence on their work to judge and jury.
- 2.15 In this way, forensic scientists could help investigators understand the nature of the crime that had been committed and the sequence of events, they could suggest which physical items and samples should be collected from the crime scene and elsewhere and what tests should be applied to them to help identify an offender either directly or from amongst a number of police suspects. They could assess the strength and check the reliability of any suggested links with specific suspect(s) in the context of the case, and then provide impartial evidence on all of this for use by the court.

OBI-Q2c. To what extent has forensic science changed since the late 1990s?

- 2.16 As a science or collection of sciences, and in response to changes in the nature and pattern of crime, forensic science is constantly evolving. The rate of change depends mainly on the level of funding available for research and development, technical developments in other fields which can be applied to forensic problems, and operational needs of police investigators. This means that some forensic fields have moved on faster than others. Four areas in

⁵ *Using Forensic Science Effectively – A Summary for Scientific Support Units - 1995 by ACPO and FSS* (pages 3-9) INQ038314

⁶ *Murder Investigation Manual by the ACPO Crime Committee (pages 41-68)* INQ038310

which most significant change has occurred are digital devices, DNA, chemical analysis, and the evaluation of scientific opportunities and evidence.

- 2.17 There have been substantial changes in **digital forensics** over the past 20 years mirroring the extent to which we now rely on digital devices in our everyday lives, and the data these devices store about us and our activities can be invaluable in police investigations. For instance, our mobile phones can indicate with whom we have been communicating – including on social media, and where we were at the time, photographs we have taken, what we have bought on-line, and CCTV cameras are now so prevalent in both public and private spaces that they can often provide snapshots of relevant footage which can help to provide a useful sequence of events, and even potentially identify individual people featuring in these. Challenges centre around keeping pace with new technology and how best to manage an ever-growing digital caseload and the associated costs. (Digital forensics is not addressed in this report).
- 2.18 By the same token the rapid expansion in digital technology and connectivity since the late 1990s means that it is much easier for law enforcement and other agencies to collect, analyse and share data, and thus identify linkages between associated crimes in a series, and the people and places suspected of involvement in them, than had been the case hitherto.
- 2.19 In relation to **DNA**, modern analytical techniques are able to analyse far smaller traces of body fluid or tissue than was possible in the late 1990s to the extent that these traces no longer need to be obviously visible to the naked eye to produce a result. At the same time, they are able to discriminate between different people to a far greater extent – routinely identifying DNA which occurs in only 1 in a billion people as against 1 in a few million people in 1998. Our National DNA Database now holds in the order of 6 million subject (people) profiles on it as opposed to the approximately 0.2 million profiles held in 1998⁷, so there is a better chance of finding a DNA match with a reference sample held on it than there was then. (Separate databases are held and managed by Northern Ireland, Scotland, and England and Wales, but with all reference profiles held centrally in the National DNA Database and linked for searching unknown crime profiles.) We can also identify male-only DNA – with the first male-only DNA profiling techniques beginning to be introduced into UK casework in 2003⁸, including their use in male and female mixtures and, as tests have developed, we can also deal far more effectively with samples in which the DNA has started to degrade. In addition, much of the processing is

⁷ INQ038229 *The National DNA Database Annual Report 2003/2004 & Forensic Information Databases Annual Report 2023- 2024 (for current figure). Both available online and published by Home Office.* INQ041424

⁸ INQ038222 *UK Forensic Science Regulator Guidance document; FSR-GUI-0013-Y-STR Profiling.* Available online from Forensic Regulators website.

now automated so we can analyse many more samples in a much shorter time and more cost effectively than we could then.

- 2.20 The position with other forms of **chemical analysis** – such as of drugs and explosives, is similar to DNA in that modern analytical techniques are able to analyse much smaller quantities of sample and pick up minor components at much lower levels than they could in the late 1990s. This means that we are able to discriminate much more effectively between different samples than we could then, and the evidence we find is likely to provide much stronger links than hitherto. In addition, these days, chemical compounds are routinely embedded within our analytical machines, and these automatically identify for us what the machine has just analysed without us having to look it up for ourselves. Analyses are also automated with the same time and cost benefits that we see with DNA.
- 2.21 Over and above technical advances, there has also been a sea change in **the way forensic science evidence is evaluated and presented**. Up until the 1980s, scientists used to consider the results of their tests in terms of whether or not they provided any support for police suspicions. But then, as part of the drive to professionalise and standardise forensic science, there was a gradual shift – first to use of a scale describing the strength of support their evidence provided to link a suspect with a crime. Then, in the 1990s, taking a more scientific approach, the FSS began to explore statistical models and developed the Case Assessment and Interpretation (CAI) system⁹. This enabled scientists to both analyse and prioritise testing options open to them, and then assess what their results meant in the context of the specific case by considering these within the framework of a hierarchy of competing propositions. These represented the respective positions of prosecution and defence. This was gradually introduced into FSS casework in the early 2000s and has now been adopted much more widely – in Europe and beyond
- 2.22 Having said all this, in some areas of forensic science we have been actively losing expertise. Some of this is to be expected as we rely increasingly on newer forms of evidence - particularly of the digital kind, or more sophisticated types of analysis which may obviate the need for further demonstration of a connection between an individual and the crime they are suspected of committing. But some of it reflects tighter budgets for public services generally.

⁹ INQ038242 *A Hierarchy of propositions deciding which level to address in casework – Science & Justice Journal 38 (4) (1998) – R Cook, I W Evett, G Jackson, P J Jones, J A Lambert*

3. Authors: Professional Backgrounds in Forensic Science

- 3.1 The main author of this report is Professor Angela Gallop for whom a summary CV is included below, with a full CV attached at Annex A
- 3.2 For much of the general content of the report, Professor Gallop has relied on her lived experience of circumstances and events in her long and varied career in forensic science, supported by some general documentary references.
- 3.3 Professor Gallop has been supported by a team of 7 other scientists, each one an expert in one particular specialist forensic discipline of those most likely to be of relevance to a consideration of scientific evidence in the Omagh Bombing and any related incidents, and as requested by the OBI for the purpose. A summary CV for each of these experts is included at the beginning of their own technical section and, again, their full CVs are attached at Annex A.
- 3.4 As Professor Gallop, these experts have relied on a combination of their lived experience and specific documentary references – in this case particularly from the document database compiled by the OBI, in drafting their responses to the OBI's technical questions.

OBI-Q3. Main Author - Professor Angela Gallop CBE

- 3.5 *Angela Gallop has been a practising forensic scientist for over 50 years. Trained as a forensic biologist in the Home Office Forensic Science Service (HOFSS), in 1986 she established the independent consultancy, Forensic Access, primarily to advise lawyers representing people accused of crime for more balanced scientific evidence at court. Then in 1997 she co-founded Forensic Alliance (later LGC Forensics) – the first independent, and largest full-service alternative to the FSS.*
- 3.6 *In addition to setting up and running forensic science laboratories, Angela specialised in the forensic science investigation or re-investigation of complex cases - personally overseeing such notable cases as Damilola Taylor, Rachel Nickell, and the Stephen Lawrence and Coastal Path murders. This was followed by co-founding Axiom International – providing criminal justice services (including forensics) mainly on behalf of the UK Government to fragile and conflict affected countries overseas. Angela was awarded a CBE for services to forensic science in the 2015 Queen's Birthday Honours.*

- 3.7 *During her career, Angela has written extensively on the use and misuse of forensic science in the UK Criminal Justice System, and has been an invited speaker to numerous scientific, legal and lay audiences, representative of independent forensic science to various Government committees, and commentator on forensic science issues on television, radio and in the Press. Most recently, she has been co-chair of the Westminster Commission on Forensic Science (WCFS) established by the All Party Parliamentary Group on Miscarriages of Justice, which reported in June 2025¹⁰.*

*Further details of Angela Gallop's career can be found at **Annex A**.*

¹⁰ INQ035703 All Party Parliamentary Group on Miscarriages of Justice Report – June 2025
https://futurejustice.org.uk/wp-content/uploads/2025/06/FS_Digital_latest.pdf

4. Scientific Tests and Techniques

OBI-Q4-7. Scientific tests and techniques available in Great Britain and Northern Ireland between 1 September 1997 and 15 August 1998 to assist the UK State in identifying those engaged in the planning and preparation of Acts of Terrorism, particularly involving use of bombs.

- 4.1 Almost any kind of physical evidence could potentially be useful to investigators of a large, complex case such as a terrorist attack – much will depend on the circumstances. For instance, in one terrorist case in England from the early 1990s, it was different soils and associated conifer needles that provided some of the critical evidence. But reflecting the list of core forensic expertise suggested by the OBI, namely, Explosive substances, Explosive devices, Fingerprints, DNA, Textile fibres, Marks and Traces, and Questioned documents, the report now focuses on the sorts of tests and techniques used within each of these that would have been available to investigators at the relevant time. A summary of the main tests and techniques described is included at **Annex B**. In each case, they have considered the same four sub-questions in the OBI's Question 5, and Questions 6 and 7.
- 4.2 Amongst the tests and techniques, emphasis is given to **finding potential evidence** to test, not just the analytical tests themselves because, unless searching is effective, no amount of powerful instrumentation will uncover any evidence that is present. This is especially true of smaller traces that may not be visible to the naked eye and explains why microscopes feature heavily as essential instruments across the different specialist disciplines. Physical and chemical enhancement techniques can also be critical to success here.
- 4.3 Similarly, the smaller an evidential trace may be, the more easily it could have been transferred as a result of some form of **unwitting contamination**, and so the more stringent the protocols for sample handling and storage need to be, and the more robust the processes for examination and analysis. Where problems can arise is when items are re-examined as part of a re-investigation. With the development of more sensitive techniques in the meantime, any contamination that might have gone unnoticed originally may now be picked up and potentially mistaken for an evidential link. Risks of potential contamination obviously extend beyond the laboratory to work carried out at the scene of crime and in connection with the collection and storage of items and samples prior to submission to the laboratory.

Any comments in this report about the approach and capabilities of FSANI are based on quality-related documents and the work done – as illustrated, for example, in case notes of examinations, print-outs of instrumental results, scientists' witness statements, and summaries and opinions expressed in reports of reviews by others – all as contained within documents on the OBI digital database. This is all in lieu of scrutinising the original case files directly and talking to the scientists themselves – which in normal circumstances would always be the preferred option.

Overall, the tests and techniques used by FSANI appear to have been broadly in line with those used by other forensic science laboratories in the UK at the material time. Differences or uncertainties about this and of access to and use of databases and other shared resources of which the authors are aware have been highlighted in the report as and where appropriate.

5. Explosive Substances

Professional background of Dr Keith Norman

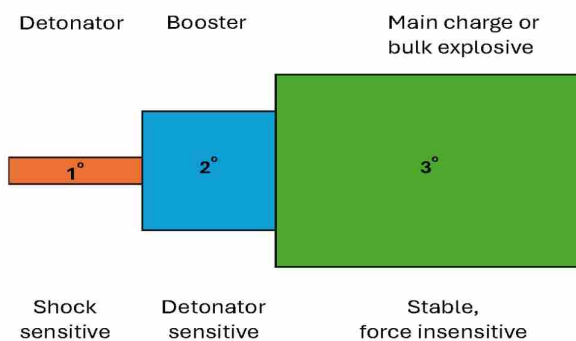
- 5.1 *Keith Norman is a highly experienced expert in forensic chemical analysis – especially in relation to drugs of abuse and toxicology, explosive substances manufacture and usage, and post blast scene examination, working within teams including a range of other technical specialists. Based in Australia, Keith has worked in the UK for an extended period, and for and on behalf of the United Nations in fragile and conflict affected regions in other parts of the world.*

*More details of his CV are included at **Annex A**.*

Brief Introduction to Explosive Substances

- 5.2 An explosive material is a chemical substance or mixture of substances which, when exposed to an appropriate amount of energy from, for example, heat, electricity, pressure or shock, will result in the spontaneous decomposition of the substance. This rapid decomposition will cause the release of a large amount of energy that has the potential to disrupt items within the vicinity. The rate or speed of decomposition is commonly known as the rate of detonation, and this is often used to classify explosive substances. (The structure and specific components associated with explosive devices are detailed under Explosive devices.)
- 5.3 Explosives are commonly categorised as primary, secondary and tertiary and these each have different functions and sensitivities. Together they form the explosive chain that, in normal circumstances, is required for the initiation of an explosion. The relative amount of each category of explosive increases along the chain from primary to tertiary, as shown in simplified form in **Figure 1** below:

Figure 1: Simple representation of the explosive chain



- 5.4 The primary explosive, the detonator, is sensitive to shock and can be initiated readily, whereas under normal conditions the secondary explosive, the booster, requires exposure to the energy released by the detonator for initiation. *(This is not always the case – for instance, ammonium nitrate can be made to form an explosive mixture through the inclusion of a range of organic, and some metallic additives.)* Finally, the main charge or bulk explosive is normally insensitive to initiation by detonators alone and will require the increased energy released by the secondary or booster explosive. *(Again, this is not always the case as some high explosives, eg. ‘Semtex’, will explode using a detonator alone).* It is the main charge that causes most of the damage from an explosion. These generic definitions relate to situations under “normal circumstances” because it is possible to modify the composition of explosives and explosives mixtures to make them more sensitive to initiation. Examples of types of explosives are included in **Table 1** below:

Table 1: Examples of types of explosives

Use	Feature	Example
Detonator	Primary Explosives	Lead azide, mercury fulminate, silver azide
Booster	Secondary Explosives	TNT, RDX, HMX, PETN
Main charge	Bulk Explosives	Ammonium Nitrate Fuel Oil (ANFO)

- 5.5 When discussing explosives, consideration should be given to the source of manufacture. In particular, commercial, industrial or military explosives are produced according to strict protocols covering their formulations, and the manner in which they are prepared, packaged and stored. This ensures that they always behave in a certain, predictable way when used as suggested by the manufacturer. By contrast, explosives and explosive mixtures can alternatively be prepared in improvised manufacturing settings using readily available commercial products which are re-purposed to create the materials required. These improvised home-made explosives and explosive mixtures (HMEs – see also under Explosive devices) will not have been tested for stability, homogeneity and exact chemical composition. As such, they have the potential to detonate spontaneously or fail to detonate effectively due to inconsistencies within their chemical formulations, or inclusion of contaminants that have deleterious effects.
- 5.6 In addition, and like other aspects of forensic science, forensic explosives examination and analysis is about far more than just the explosive substances themselves. This is because the potential for detecting a specific type of evidence in a laboratory setting is reliant on the manner in which the relevant

exhibit was collected and how it was treated (for example, stored and transported) up to the point of laboratory examination, and then precisely what that examination entails.

- 5.7 The exhibit collected has to be representative of the item, material or environment that it is derived from. It has to be collected in such a way as to avoid adding – through contamination, or removal of any significant material of potential interest. The very act of collecting a sample could change the composition of the material. From a chemical perspective, this could be due to evaporation of low boiling point material through exposure to the atmosphere, or interactions with the sample collection equipment resulting in adsorption onto its surfaces and thereby reducing the concentration in the final mixture. Once collected, the exhibits have to be stored in a way that minimises further degradation of the material of interest which could again render the subsequent analysis inaccurate.
- 5.8 For analysis to be undertaken, there obviously has to be some manipulation of the exhibit. This could be in relation to the extraction and concentration of trace amounts of explosive residues from surface swabs collected from the scene of the incident, and then the isolation and identification of the compounds/materials of interest. The degree of sample preparation required for each type of analysis is dependent upon the concentration of components of interest in the original exhibit.
- 5.9 The final aspect that has to be considered is the manner in which the analytical data is interpreted. Unequivocal identification of a specific chemical compound requires that the identification be substantiated through direct comparison with the same compound obtained in a pure form, or known formulation, analysed by the same methods providing the same results. This requires analytical standards, of known purity, stability and origin, be prepared and analysed using the same analytical process, and for them to provide the same analytical response as the exhibit.
- 5.10 Data interpretation also has to account for the matrix from which the sample was extracted, the formulation of the material of interest, any degradation or changes in structure due to sample preparation and ultimately any effects that the analytical method may have on the compound. This level of acceptance is achieved through the validation and verification of the entire analysis process for a given evidence class of chemical substance. It is only once the validation and verification process has been completed that analysis results can be accepted and used to prove, or disprove specific hypotheses associated with the exhibit and therefore the case.

OBI-Q5a Overview of each test and technique that was available to the UK State between 1 September 1997 and 15 August 1998 for use in police investigations

- 5.11 The aim of chemical analysis is to identify the specific chemical compounds or components of interest in a sample. This can be achieved through a number of processes with varying degrees of sensitivity (the amount of material required to produce a result) and specificity (the power required to discriminate one compound from another) depending on the accuracy required of the final result.
- 5.12 *The only organisation that can provide a definitive list of the tests and techniques available to the UK State at the material time is the Forensic Explosives Laboratory (FEL) where all the non-Northern Ireland work was performed. But* based on Document INQ011659¹¹ the following analysis methods were used for the examination of bulk and trace explosives identified in casework samples at the relevant time:
- Spot tests
 - Burn tests
 - Fourier Transform Infrared Spectroscopy (FTIR)
 - High Performance Liquid Chromatography – Electrochemical Detection (HPLC/ECD) for the detection of organic compounds
 - Ion chromatography anions, cations, sugars quantitation of nitrates
 - Gas Chromatography – Flame Ionisation Detection (GC/FID) for the detection of organic compounds
 - Gas Chromatography – Thermal Energy Analysis (GC/TEA)

Examples of effective and efficient analysis regimes suitable for the detection of drugs and explosives are detailed in the recommendations by the Scientific Working Group for the Analysis of Seized Drugs (SWGDRUG)¹² and the Recommended Guidelines for Forensic Identification of Intact Explosives from TWGFEX/SWGFEX¹³. Both guidelines detail a range of categories of tests

¹¹ INQ011659 (pages, 2,4,5)

INQ038244 SWGDRUG. Vol. Version 8.2 (ed United States Department of Justice Drug Enforcement Administration) (Executive Office of the President Office on National Drug Control Policy Counterdrug Technology Assessment Center, 2024).

¹³ INQ038230 Technical/Scientific Working Group for Fire and Explosives Analysis (TWGFEX/SWGFEX) (ed TWGFEX Laboratory Explosion Group Standards & Protocols Committee) (National Institute of Standards and Technology, 2018).

with increasing levels of specificity. The inclusion of both guides for our purposes here reflects the similarities in the range of sample types that need to be considered. For both explosives and drugs, the methods of analysis have to be effective for both bulk, and trace amounts of material - the traces having been collected through either swabbing, or extraction from evidential materials. The analysis regime in place in the late 1990s as detailed in INQ011659¹⁴ would meet the requirements for the formal identification of explosive compounds and mixtures.

While there were a very wide range of other chemical techniques and analytical processes which could theoretically have been used at the time for analysing the chemicals and chemical residues associated with explosives, it seems unlikely that these would need to have been resorted to. For instance, methods for identifying and comparing specific forms, or isotopes, of organic and inorganic materials including in explosives, were available at the time. But the ubiquity of ammonium nitrate, absence of any analytical results databases relating to specific sources of it produced, imported and sold in Ireland in the years prior to the Omagh incident, and the potential for it to have come from mixed sources, mean that the technique would be unlikely to have provided much if any meaningful additional information.

Spot Tests

- 5.13 Spot, or colour tests represent the simplest of identification techniques amongst those deployed for explosive compounds. This type of test relies on the formation of a colour when a specific chemical reagent is added to the sample being tested. Such tests are very useful for the initial, general identification of the type of explosive compound involved but they require relatively large amounts of starting material and they do not provide a detailed identification. In other words, they are not very sensitive nor very discriminating.
- 5.14 Spot tests can be used at crime scenes as a presumptive test to establish whether or not there is a need to investigate a potentially suspicious substance further. In the laboratory, the spot test can be used to establish the broad class of material present and, as such, provide some direction for the analysis regime to follow. Whenever such tests are used, consideration should always be given to the sensitivity of this type of test and the potential for false positives and/or negative results from it.

¹⁴ INQ011659 (pages 2, 4,5)

An example of a common colour test indicating the presence of nitrate esters and nitramines – which are found in explosives, is the Griess Test¹⁵. A positive reaction in this test is indicated by the production of a pink colour¹⁶. But while the aim of the colour test is to identify the presence of explosives and explosive mixtures, it also has a variety of other applications eg. to identify the presence of nitrates in urine¹⁷. As it is not specific for the presence of explosives, it can therefore result in the generation of “false positive” results from detection of innocuous materials. A positive Greiss test result was at the centre of the conviction of ‘The Birmingham 6’ for the murder of 21 people in two Birmingham pubs in 1984, until 20 years later it was shown that the result could alternatively have arisen from a number of other things – including the playing cards the men had been using at the time.¹⁸

Burn Tests

- 5.15 The concept of the burn test is to establish if a material is able to be burnt, and the sequence of events that occurs if this happens. There are three possible outcomes for this test, namely, that the substance:
- a) Fails to ignite
 - b) Ignites and burns; or
 - c) Explodes
- 5.16 The duration of the combustion, or the time to explosion, may provide additional information¹⁹. This is a rapid, destructive method to establish if the material collected as evidence is a primary explosive or a combustible material. However, combustible materials could also include a wide range of organic substances that may or may not be involved in the production of explosives and explosive mixtures.
- 5.17 Additionally, as this is a destructive method of analysis, repetitive testing can consume the whole of an exhibit. To this extent, the test would normally only be undertaken when there would be sufficient sample left for potential further testing, and not where only trace amounts of explosives material were available.

¹⁵ INQ038262 Almog, J. & Zitrin, S. in *Aspects of Explosives Detection* (eds Maurice Marshall & Jimmie C. Oxley) 41-58 (Elsevier, 2009).

¹⁶ *ibid.*

¹⁷ INQ035722 Zhang, M., Truver, M. T., Hoyer, J. L., Chronister, C. W. & Goldberger, B. A. Presumptive identification of nitrite by Griess reagent test strips—Case reports of fatal poisoning with sodium nitrite. *Journal of Analytical Toxicology* 47, 746-749 (2023). <https://doi.org/10.1093/jat/bkad038>

¹⁸ INQ038241 BBC News website 2011 - 20 Anniversary of Acquittal

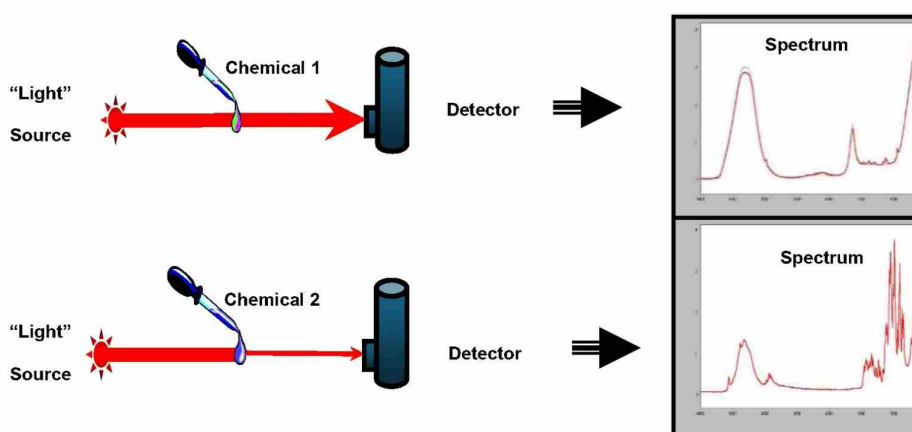
¹⁹ Nations, U. Vol. ST/SG/AC.10/11/Rev.7 (ed United Nations Economic Commission for Europe (UNECE)) 536 (United Nations Economic Commission for Europe (UNECE), New York and Geneva, 2019).

INQ035709

Infrared Spectroscopy

- 5.18 Identification using spectroscopic techniques is achieved by measuring the absorbance, transmission, or reflectance of different wavelengths of light in a 'light source' when they interact with the sample of interest. This results in the production of a line graph or spectrum which is specific for each particular compound. The compound of interest can then be identified by comparing its spectrum with spectra from a range of known compounds within a 'library'. An example of this concept is shown in **Figure 2** below.

Figure 2 Concept of Spectroscopy



- 5.19 INQ011659²⁰ details the use of **Fourier Transform Infrared spectroscopy** as one of the analysis methods used during the examination of exhibits. Here, an infrared light source is used, and multiple scans are conducted, improving the sensitivity of the method.
- 5.20 There are some limitations to this method – for example, it can be difficult to obtain accurate spectra from watery solutions or wet samples. As there is normally no sample separation undertaken in connection with FTIR, identification of specific compounds in a complex mixture may be difficult to achieve. So while the analysis technique is relatively easy to undertake, the interpretation of the resulting spectrum and identification of the compound(s) present is likely to be more complex and require an enhanced level of expertise and experience.

²⁰ INQ011659 (pages 2,4,5)

Chromatography

- 5.21 Chromatography is a technique for separating different components in a sample through its chemical and physical interactions with a stationary (fixed) phase such as a thin layer of dried powder on a plate or a tube filled with a specific chemical compound, and a mobile phase of either gas or liquid which is passed through it.
- 5.22 A number of different types of chromatographic techniques are commonly used in routine chemical analysis. These can be grouped as liquid, gas or ion based chromatographic methods - depending on the nature of the mobile phase.

Liquid Chromatography

- 5.23 Thin-layer chromatography is liquid chromatography in its most basic form. It involves making an extract of the sample of interest and applying a spot of this near to one end of a thin, powder-covered plate. The plate is then stood upright – spot end down, in an appropriate chemical solvent, and the solvent allowed to rise up the plate (by capillarity) taking the extract with it and separating it out into its component parts on the way. The pattern of components on the plate enables the sample to be identified and/or compared with other samples of interest.

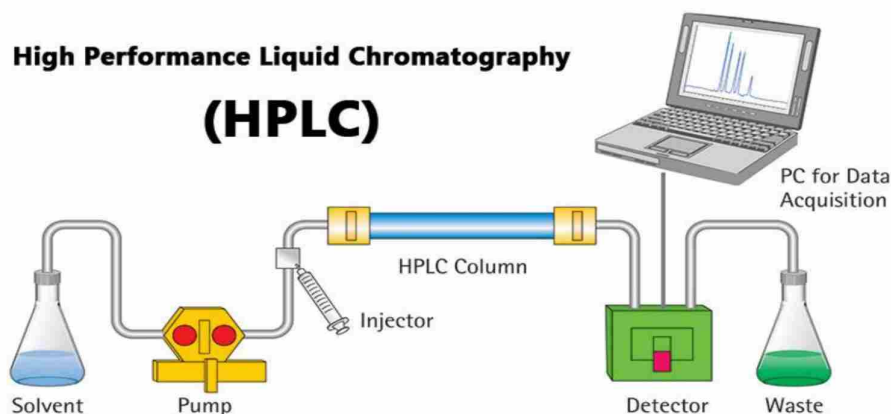
High Performance Liquid Chromatography (HPLC)

- 5.24 INQ011659²¹ describes the use of high-performance liquid chromatography (HPLC) in the late 1990s for the separation of commonly expected materials associated with explosives and explosive mixtures. INQ011659²² indicates that the detection system associated with the HPLC was an Electrochemical Detector (ECD). In this technique, the mobile phase or liquid is actively pumped through a column of separation media, the stationary phase. An extract of the sample of interest is injected into the system, and an Electrochemical Detector (ECD) then analyses its components as they emerge from the end of the column. It is the order in which they emerge which identifies them when compared against known standards analysed under the same conditions. A schematic of the system is shown in **Figure 3** below.

²¹ INQ011659 (pages 2,4,5)

²² INQ011659 (pages 2,4,5)

Figure 3 Schematic of a High Performance Liquid Chromatography (HPLC) system



Ion Chromatography

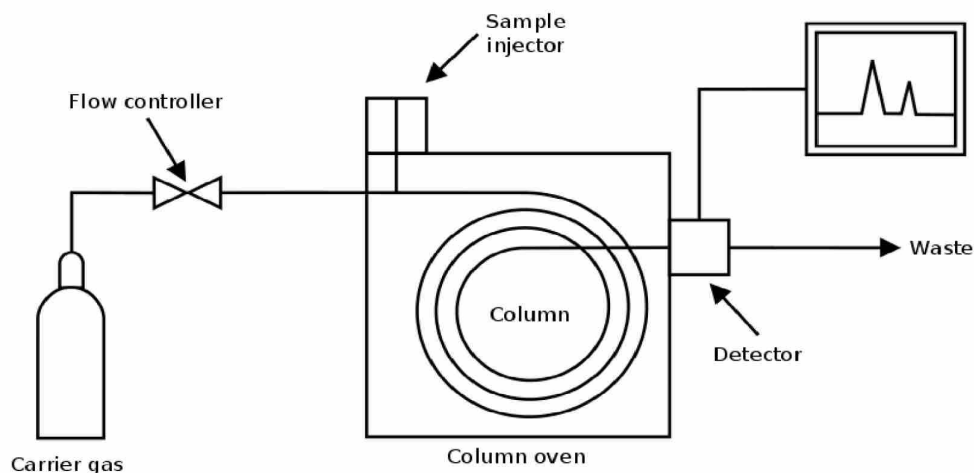
- 5.25 Ion chromatography (IC) can be considered as a subset of liquid chromatography. In this system, separation of components within a sample of interest is achieved as a result of the electrostatic interactions between electrically charged fragments in the sample, and oppositely charged functional groups bound to the stationary phase²³. The sample components are then detected either by changes in electrical conductivity, or by absorption of (UV and visible) light.

Gas Chromatography

- 5.26 Gas chromatography (GC) uses the same concepts of a mobile and a stationary phase for separation but where the mobile phase is of gas, not liquid as shown in **Figure 4** below. For gas chromatography, the compound(s) being tested have to be volatilised (or vaporized) and to remain stable during the analysis. This means that if the material is non-volatile, or degrades when heated to a high temperature, it will not be suitable for GC analysis.

²³ INQ035721 Alexandre Varão, M., José Domingos Santos da, S. & Priscila, G. Ion Chromatography: Principles and instrumentation. *Orbital: The Electronic Journal of Chemistry* 14 (2022). <https://doi.org/10.17807/orbital.v14i2.15871>

Figure 4 Basic Schematic of Gas Chromatography (GC) System



- 5.27 INQ011659²⁴ indicates that, at the material time, the detectors associated with GC systems were Flame Ionisation Detection (GC/FID) - where components of the sample of interest were burnt in a hydrogen flame, and Thermal Energy Analysis (GC/TEA) where they are passed through a pyrolyzer. The pyrolyzer detector is extremely sensitive for the detection of nitro containing compounds and, as such, is suitable for the examination of a range of common explosive materials.
- 5.28 Document INQ015152, titled "Quality management system manual from FSANI titled 'Explosive residue detection by GC/TEA,' Issue 4, dated 07/07/1998."²⁵ listed the reference materials used for the validation of the GC-TEA system used in FSANI.
- 5.29 Document INQ015152 further details a list of compounds that did not produce a response from the GC-TEA system and as such would not be detected if present in the sample.

OBI-Q5b How widely used or established was each test or technique, and were there any limitations on its use?

- 5.30 All of the analytical techniques referred to above are still commonly used today for the examination of explosive materials.
- 5.31 The principal limitations of the methods listed by FSANI for explosives cases relate to the specificity of detection of explosive related compounds. While

²⁴ INQ011659 (pages 2,4,5)

²⁵ INQ015152 (pages 7-8)

having analytical methods that are sensitive and specific for the materials of interest is obviously beneficial in casework examinations, failure to include a general screening method may result in missing compounds that are not specifically explosives but may be associated with either the formulations or preparation of such materials/mixtures. Such a general screening method would be non-specific, but sufficiently sensitive to detect and identify all of the components – both explosive related and others, present in the sample under examination. *It would therefore provide more points of comparison between samples from different locations and highlight whether any additional compounds detected were associated with the explosive substance itself as opposed to the background on which it was lying.*

- 5.32 The techniques detailed in INQ011659²⁶ were developed and employed for the detection and identification of specific explosives, and explosive mixtures that were commonly seen during this era. These days, global explosives analysis is undertaken as a qualitative process and not generally as a quantitative one. This is due to the lack of homogeneity in improvised explosives and the fact that the analysis of post-blast material only detects those components that have not been consumed during the explosion. As such, their specific ratios will have minimal bearing on the composition of the original bulk explosive, prior to detonation.

OBI-Q5c How were these tests and techniques used practically?

- 5.33 The analytical techniques detailed above were used in a sequential manner to identify the explosive, or explosive mixture, present in exhibits provided for analysis as follows:
- 5.34 The analysis process would initially involve visual examination of the exhibits to identify amounts of the suspected explosive material in them including examination of the bulk material. This would be subjected to non-destructive testing to minimise the amount of sample consumed during the analysis. An example of the sort of non-destructive test used here would be FTIR. For this test, a small amount of the material would be 'illuminated' by a beam of infrared light and the resulting spectrum would be collected for detailed scrutiny,
- 5.35 Following this, the samples would be subjected to the spot and burn tests to establish the general class of the material, and particularly if it were an explosive material. The material would then be subjected to the various instrumental methods to confirm the presence of the explosive compounds. Volatile organic compounds would be identified using GC-TEA, while non-volatile organic compounds would be identified using HPLC-ECD with the

²⁶ INQ011659

inorganic salts and sugars identified using IC. Following completion of this analysis suite, a conclusion would be drawn as to the composition of the explosives/explosive mixture present.

Improvised explosive mixtures obtained from a suspect, device or following an incident, are derived, in the most part, from commonly available household or agricultural items – such as fertiliser and fuel oil, which have been repurposed to make an explosive device. The number of different sources potentially available, and the improvised manner in which the explosive material is prepared, with variations expected during its mixing/processing, storage and transportation, means that there may be no way accurately to determine whether or not samples of explosive mixtures were created from the same batch and may therefore have been associated with one another. And even if they were, what this might mean, if anything, in the context of a rural environment. This is why the emphasis when analysing explosives substances is on identification of the material and not on comparisons with potential specific sources as this may be misleading – see also paragraph 5.12 and the Marks and Traces Section, Section 10 of this report.

In addition, in post-blast samples, the chemicals being investigated have been exposed to extreme heat and pressure during the explosion and may have chemically interacted with the surfaces on which they are lying. Attempting to identify the original source of the components in such complex samples may not be possible.

OBI-Q5d What sort of forensic material, and how much was required for reliable use of the tests and techniques?

5.36 When considering explosives analysis, two scenarios must be taken into account. These are:

- The identification of visually identifiable amounts of the suspected explosive material collected from a manufacture location, from a device that had not detonated, or from a device where detonation did not result in the complete consumption of the explosive materials.
- The identification of residues collected from surfaces where materials have been stored, prepared, transported or handled, or from debris associated with the explosive device or other associated debris following detonation of the device.

5.37 As to the amount of material required, it is common to require less than 5 grams of the bulk material – roughly equivalent to a small teaspoonful, for the conclusive identification of the compounds present. This will allow for

homogenisation of the sample to provide the average composition expected in the bulk material. Depending upon the types and sensitivity of the material, multiple subsamples would normally be collected and analysed to prove the overall composition of the bulk explosives. However, in cases where the material is friction sensitive or has the potential for spontaneous detonation during handling or storage, only amounts less than that expected to detonate would be collected for examination.

- 5.38 For trace amounts of the explosive materials including on surfaces that have been in contact with the bulk explosive or with the gases evolved following detonation, these would be swabbed for examination. The swabs would be extracted, and then the extract subjected to an instrumental method such as GC, IC or HPLC. The results of analysis would show the compounds remaining following contact with the explosives or those present after a detonation. These may be a subset of those present in the bulk samples as there is a potential for loss of certain chemicals due to evaporation, decomposition, or consumption during exposure to the environment and the act of detonation.

OBI-Q6 Were any of the tests and techniques available between 1 September 1997 and 15 August 1998 believed to be unreliable at the time, but have subsequently proved to be reliable?

- 5.39 All of the tests and techniques used during the timeframe in question were considered to be reliable and reproducible at the time and, indeed, many are still used in forensic analysis today.
- 5.40 The move away from some of the methods may be due to the evolution of new techniques, changes in the composition of samples of interest requiring alternative analytical approaches or increasing sensitivity of analytical methods allowing for modifications to the analysis regime.
- 5.41 Consideration would have been given to growing awareness about occupational health and safety, and options to remove hazardous materials from the analysis process through substitution of methods, such as the HPLC-ECD method which used a mercury electrode.
- 5.42 Finally, changes in the analysis protocols may have been as a result of emerging trends in the materials expected at incidents of interest, research and development into explosives analysis, and as part of the recommendations from international bodies and judicial reviews suggesting alternative processes.

OBI-Q7 Were any of the tests and techniques available between 1 September 1997 and 15 August 1998 believed to be reliable at the time, but have subsequently proved to be unreliable?

- 5.43 The limitations of the Griess test as a presumptive test requiring confirmation would have been well recognised by the late 1990s, especially when this was demonstrated and used to secure the acquittal of the Birmingham 6 in 1991. To this extent, the test is still used but only for initial screening (triaging).
- 5.44 There are no other tests or techniques amongst those described above which have subsequently been acknowledged as unreliable.

Explosive Substances Summary

- 5.45 *The FEL is the only organisation which can provide a definitive list of the tests and techniques available to the UK State for Explosive substances analysis at the relevant time as they handled this aspect of police investigations for all bombing incidents in Great Britain.* Based on the information supplied by FSNi in document INQ011659²⁷, the analytical methods used for the examination of explosives would have been fit for purpose.
- 5.46 The analytical protocol was solely focused on a very small number of predominantly nitro-based explosive compounds. This reflected the use of these compounds in devices in previous incidents.
- 5.47 The main limitation that is evident from this list of techniques and the analytical approach suggested is that there would have been no routine screening of samples for “other” compounds. While not explosive themselves, these compounds could have been incorporated in the explosive material during manufacture or usage – perhaps forming part of commercial products used in the preparation of improvised explosives, and therefore might have been able to add strength to any suggested associations. However, this is merely supposition as there is no evidence either way.

²⁷ INQ011659 (pages 2,4,5)

6. Explosive Devices

Professional background of Chris Hester

- 6.1 *Chris Hester joined the Metropolitan Police in 1995 and as a beat duty constable he was one of the first police officers on scene at the 1999 bombing of the Admiral Duncan Pub in Soho, London.*
- 6.2 *He spent twenty three of his thirty years in the police working within Counter Terrorism and has been involved in the investigation of many significant terrorist incidents in the UK. He joined the SO13 Anti-Terrorist Branch in 2002 working in a small specialist team within the CT Specialist Search Unit dealing predominantly with the threat to Great Britain from Dissident Irish Republican Terrorist Groups Improvised Explosive Devices (IED's), improvised mortars and direct fire weapons systems.*
- 6.3 *In 2014 Chris joined the United Kingdom Police National Bomb Data Centre (BDC) as one of the four Bomb Scene Investigators covering the UK. During his eleven years in the BDC he has been involved in a number of post blast/bomb scene investigations, most notably as the lead investigator for the 2017 Manchester Arena bombing. His role as a Bomb Scene Investigator was primarily to identify the component parts of any IED present and perform the technical and tactical categorisation of any such device.*
- 6.4 *Chris retired from the police in November 2025 and is now an independent forensic consultant specialising in IED and post blast investigation and delivering post blast training in the UK and overseas on behalf of the UK government.*

*More details of his CV are provided at **Annex A**.*

Brief Introduction to Explosive Devices

- 6.5 Explosive devices can be regarded as any item or instrument specifically constructed to rapidly release, under some form of control, significant energy. Technically speaking, explosive devices range from party poppers or a Christmas cracker at one end of the spectrum to a nuclear warhead at the other.
- 6.6 Explosions can be caused by three mechanisms; physical (also referred to a mechanical), chemical and atomic²⁸. In relation to this Inquiry, explosive

²⁸ *The Chemistry of Explosives (3rd Edition) by J Akhavan (page 27). Published 2011 by RSC Publishing.*

devices relate to items using chemical compounds which contain stored energy which is released when the appropriate stimulation is applied.

- 6.7 There is a distinct difference between explosive devices constructed using conventional manufacturing processes following standardised designs - such as an L109A2 fragmentation hand grenade which is an item of military ordnance, and improvised devices - also known as Improvised Explosive Devices (IED's), which may follow a general design or be a 'one off' and are built using consumer available materials and/or parts that have been adapted or constructed using improvised methods specifically for the device.
- 6.8 Whilst military ordnance uses explosives explicitly formulated or adapted for each type of device and manufactured to an exacting standard by professional explosives companies, improvised devices may be found to contain any explosive available to hand, be it commercial, military or Home Made Explosive (HME) or potentially a combination of any or all three.
- 6.9 HME's are manufactured or synthesised in an improvised manner from chemicals or compounds which are available to either the general public or have limited restrictions on acquisition. A common and relatively easy method of producing an HME is the combination of two binary components which are individually comparatively safe or inert but become explosive when appropriately and homogeneously mixed in the correct ratio. These HME's are referred to as Fuel Oxidiser (FOx) explosives.

Component parts of IEDs

- 6.10 The explosive in an IED forms one part of the five component parts needed to construct a device^{29, 30}. The five components are:

Switch: One or more switches may be present in an IED. The switch is the method of changing the state of the IED from unexploded to exploded. There may be more than one switch in an IED and these are generally referred to as an arming switch and a firing switch. The arming switch is used as a safety mechanism to ensure the IED does not explode when the person planting the device sets it; this can either be in the form of a delay timer or a circuit checker. The firing switch is the final switch which activates the device.

Power Source: A power source is required to precipitate the chain reaction which results in the main charge exploding. In the majority of cases, the power source is electrical and in the form of a battery or batteries.

²⁹ INQ041352 UNMAS IED Lexicon, <https://www.unmas.org/en/improvised-explosive-device-lexicon>

³⁰ INQ001031 (page 3)

Initiator: The initiator is the bridge between the power source and the explosive main charge. The initiator takes energy from the power source and converts it into heat and light. Terminology is unkind within this subject as all detonators are initiators, however not all initiators are detonators. Initiators primarily contain a combustible material or low explosive and produce a flame front which is sufficient to stimulate a low explosive main charge to explode. An initiator, on its own, is unable to produce sufficient energy to stimulate a high explosive to explode. Detonators generally contain a small quantity of primary high explosive and slightly larger quantity of secondary or booster high explosives. When sufficient input energy is introduced, the primary explosive detonates producing a shock wave which, in turn, detonates the secondary/booster (see also Explosive Substances).

Container: The container for an IED is commonly considered to be the outer packaging to carry or conceal the device, for example a rucksack. For the police investigator, as well as any outer packaging, each individual component has its own container whether it be the body of a mobile phone used as a switch or a bag containing HME.

Explosive main charge: The explosive main charge of an IED is the payload designed to explode and cause damage and/or physical injury. The main charge can be either a low or high explosive dependent on a number of variables such as what explosive is available or accessible to the bomb maker, what is their target and intended outcome and what detection or security check points the IED must pass through.

- 6.11 The order and mnemonic used for these five components may vary from country to country or organisation to organization, however, the five components always remain the same. By example, the word 'Packaging' may be exchanged for 'Container' however the function of the items within the IED remain equal.
- 6.12 All five parts of the device must be present, working and connected appropriately or the device will fail to function as designed. The terms "viable" and "non-viable" are often used to differentiate between an IED that has all the parts correctly working and connected and will explode when designed to do so, and an IED where (usually) one or more parts are either not connected or not working correctly, or are missing.

IED extras or enhancements

- 6.13 In addition to these five essential component parts, there are additional components commonly referred to as "extras or enhancements". These are not an essential part of an IED; a bomb will still function without them. Extras

or enhancements are items added to the device to increase the effects of the bomb. An example of this would be nails or ball bearings added to an IED as fragmentation and designed to increase the lethality of the device when used in proximity to people. The bomb would still function without the nails or ball bearings but the 'effectiveness' may be reduced without them.

OBI-Q5a Overview of each test and technique that was available to the UK State between 1 September 1997 and 15 August 1998 for use in police investigations.

Searching for IED components

- 6.14 The identification of component parts of an IED was conducted in two distinct phases; the first phase was carried out during the scene search^{31, 32} and remediation process, and then the second phase occurred during the evidential sift within a forensic facility and was primarily facilitated by manual observation.
- 6.15 In the aftermath of a bombing, once any injured people had been evacuated to hospital, a search of the scene was conducted by investigators, normally the police with military assistance in some instances. During this search, the seat of the explosion would be identified along with damage patterns to assist in the initial potential identification of the general type and quantity of explosives involved. This initial identification was obviously subject to confirmation or amendment by subsequent objective forensic analysis of any explosive traces recovered from the scene. The search would also have focused on locating and identifying the component parts of the device. Initial witness accounts would have assisted in this process in potentially identifying the origin of the explosion which may have given the investigators a reference with which to start.
- 6.16 The efficacy of the tests and techniques applied would have been largely dependent on the state of the scene at the commencement of the investigative process and the availability of usable evidence. An explosion that was confined, for example within a building, would likely yield more evidence than a scene in the open air. In the latter case, not only would the debris be dispersed over a wider area, but the scene would also be subject to the prevailing weather conditions. Likewise, an explosion that occurred in an area with little or no human activity nearby would show less disturbance of the debris and by extension, more usable evidence, than a scene in a busy environment where victims and rescuers will inadvertently destroy or remove

³¹ INQ026552 (page 8)

³² INQ013686 (page 11)

evidence in the aftermath of the explosion³³. Any subsequent fire at the scene of an explosion would in all likelihood destroy any usable evidence and the actions of the fire service in dealing with any fires would also play a major role in the survivability of evidence as debris is often washed away into the drainage system. Finally, the prevailing weather conditions might also play a part in both the quantity and quality of any recovered parts of the device.

Identifying IED components

- 6.17 The identification of IED component parts after an explosion was a skill learnt from both specialist training and operational experience³⁴. Possession and an understanding of up-to-date intelligence on terrorist tactics, techniques and procedures (TTP's) also assisted in the process³⁵ however every scene would have been approached with an open mind as to the design of the IED. Investigators would have searched primarily for physical evidence of four of the five components; switches, power sources, initiators and containers.
- 6.18 The explosive main charge used in a device in most instances would have been completely consumed in the explosion and Explosive Trace Recovery Kits or an equivalent would have been used to swab for explosive residue at the scene. These swabs would have been submitted to an appropriate forensic laboratory for analysis and the results communicated to the investigation team. Presumptive spot testing for explosives at the scene using reagent colorimetric methods were available (see also Explosive Substances), however these were regarded as only indicative within the legal process, requiring confirmation. There have been no documents supplied to show that any presumptive spot testing was conducted at the Omagh bomb scene³⁶ however not all scenes are suitable for this kind of testing for a multitude of reasons, and no adverse conclusion should be drawn from this testing not being performed.

Initial search of the bomb scene

- 6.19 The physical search for evidence within a bomb scene usually involved a progressive process which included an initial walk-through to recover any immediately obvious evidence, followed by a sweep and sieving/sifting to identify smaller items of interest, and then a final fingertip search to ensure that the smallest fragments had been recovered. During these phases, any items that might have constituted a component part would have been identified for further examination within a forensic facility. Items of interest might have been photographed at the scene or a sketch drawn to assist in the identification process.

³³ INQ013686 (page 11)

³⁴ INQ013687 (page 10)

³⁵ INQ026552 (page 8)

³⁶ INQ035832 (sheet 1)

- 6.20 In the case of a large bomb scene with substantial debris, in order to return the area back to 'normality' as pragmatically as possible, it might have been necessary to remove debris from the scene in bulk for subsequent sieving/sifting using mechanised equipment. In these instances, plant might have been used to remove the debris after the initial walk-through search has been completed. The removed debris would have been transferred to a secure location at an acceptable distance from the scene where the process could be carried out without undue time pressures being applied in order to re-open the scene³⁷. Once the bulk debris had been removed from the bomb scene, the final fingertip search was then carried out.
- 6.21 All of the items recovered, whether already identified as 'of interest' or not, would have been forensically packaged and recorded prior to final removal. The packaging might have been for a single item which is individually packed due to its potential significance, size/shape or forensic vulnerability, or a large sealable plastic packing crate filled with loose debris. The unique exhibit number allotted to each piece of evidence which was entered into the log allowed the item to be tracked throughout the subsequent forensic processes.

More detailed search at the forensic facility

- 6.22 The second, more detailed search of all the recovered debris would then have been conducted in slower time at the appointed forensic facility. This allowed for a minute analysis of every fragment and often revealed small sections of components that may have been combined with other items such melted plastic or fabric. This process was significantly slower to undertake but should have ensured that no piece of evidence was missed.

Comparisons between devices

- 6.23 The physical forensic comparison of components from one device to another was conducted by relevant forensic scientists, be it DNA, tool marks, machine fit etc³⁸. It should be noted, however, that these examinations would generally be for one specific component against another. For example, two pieces of red wire from two different bombs could be compared against each other and revealed to be from the same spool, however, the design of the device in which the respective wires were used could have been different.
- 6.24 The contextual comparison of devices was normally conducted by police officers or forensic scientists specialising in IED's and the military Weapons Intelligence Section. A method used to assist in this process involved ascribing

³⁷ INQ026552 (page 8)

³⁸ INQ024869 (Page 20)

a Mark (Mk), or version number, to a particular design of device. Detailed records of the components of all devices encountered were kept, and searches could be made to compare the design, construction and details of the components used against each other³⁹.

- 6.25 These records may have assisted in differentiating two IED's that are, on initial appearance, the same. Further investigation might have shown that whilst the devices are both of the same design and functionality, there are subtle, fundamental differences in their construction. This could be because two bomb makers building devices to exactly the same design, purchase rocker switches from two different suppliers due to their geographically different locations. There will also often be small but identifiable differences in the construction techniques. The joining of two wires together, for example by soldering, is often a significant identifier as it is unlikely that two individuals will separately use a completely indistinguishable method or technique from each other^{40, 41}.
- 6.26 Whilst this method of identification is relatively subjective, appropriate complementary forensic analysis of the components provides objective support to the conclusions⁴².
- 6.27 The use of Mk's to categorise IED's can also assist where there are two devices that at face value are visually entirely different, however, when a system analysis of their circuit designs is performed, these are shown to be the same. They could be two devices with different outer containers, different branded rocker switches, different coloured LED's and different electro-mechanical timers. The batteries in each could be varied - one could use a 9v PP3 battery and the other could have six 1.5v AA batteries in a holder, however, when a circuit diagram of both devices is drawn, they are both found to be the same and are therefore categorised as the same Mk⁴³.

OBI-Q5b How widely used or established was each test or technique, and were there any limitations on its use?

- 6.28 The tests and techniques used in the police part of the investigation of the Omagh bombing were commonly utilised in both Northern Ireland and the

³⁹ INQ026552 (page 14)

⁴⁰ INQ011671 (page 23)

⁴¹ INQ012876 (pages 1-4)

⁴² INQ034596

⁴³ INQ021552 and INQ024797

mainland in bombing attacks both before and after the incident. There is nothing to suggest in any reporting that any new or novel tests or techniques were employed, nor was there a departure from the tried and tested methods previously used.

- 6.29 One limitation of the tests and techniques for identifying and comparing the component parts of an explosive device is that they will generally only assist in identifying a bomb maker or those involved in the intimate assembly of a device and not necessarily the person(s) planting it⁴⁴. Whilst the bomb maker has to be 'hands on' with all of the elements of the device during its construction, by contrast the bomb planter's physical contact with the device may be limited only to pressing a switch or turning a dial, seriously reducing the forensic opportunities for identifying them.

OBI-Q5c How were these tests and techniques used practically?

- 6.30 As outlined above, main aspects of the role of the bomb scene investigator included:
- examining and assessing the scene of a bombing and making deductions about the type of bombing device used, and how this was likely to have been deployed
 - finding and recovering any potentially significant items – such as IED components or fragments of components, and then examining these in detail in conjunction with forensic scientists to understand how they had been assembled, and any similarities with devices used in other, potentially related bombing incidents which might suggest links with these
 - Similarly, working with forensic scientists to consider and explore any further forensic opportunities – such as fingerprints and DNA on IED components, for identifying who might have been responsible for making, or handling them.
- 6.31 To this extent, a central focus for tests and techniques related specifically to IEDs and their component part identification and comparison, and when the use of detailed photography, notes and diagrams were normally used. A visual appreciation of the item would have been carried out, primarily to identify the overall role of the component part (power source, switch etc) and then to sub-categorise the item, for example either a rocker, toggle or slider switch.

⁴⁴ [INQ025253 \(page 449\)](#)

- 6.32 Identifying features including colours, materials and any serial numbers or makers marks would have been fully noted. These features would then have been entered into some form of database or register and checked against any pre-existing items that might have shared the same characteristics. This may have involved an alpha-numeric search and comparison of markings, measurements of the item or parts thereof and/or a visual comparison.
- 6.33 In some circumstances, it might have been necessary for a further physical examination of items thought to be component parts to have been carried out, especially in instances where the components may have been severely damaged and broken and some form of manual 'dry' reconstruction was needed to piece a number of the broken fragments back together.

OBI-Q5d What sort of forensic material, and how much was required for reliable use of the tests and techniques?

- 6.34 Any material that could possibly form part of the IED would have been subjected to component part identification and comparison. It is almost impossible to define the type and quantity required as each scene and each fragment is unique. A tiny fragment of virtually unrecognisable debris may, under close and diligent scrutiny reveal part of a serial number which when searched against the database, reveals its true identity. Likewise, many small, damaged items which in isolation are unidentifiable, may be re-assembled - much like a jigsaw, to a state which then renders the original item from which they came recognisable and identifiable.
- 6.35 Decisions about whether or not to subject an item for subsequent physical forensic testing, and what the most appropriate testing or technique should be, would ultimately not have been the decision of the police investigator. Police officers at the scene of a bombing would collect every piece of evidence which might possibly have been connected with the device or yield some usable information, irrespective of its size or condition. In doing so, they would have been mindful of the physical characteristics of different types of material and which materials might yield a better forensic outcome over others, such as a piece of hard smooth plastic versus a piece of fluffy fabric. A fingerprint, if present, would be recovered more effectively from the plastic however the fabric would provide better fibre evidence.
- 6.36 The police would have submitted evidence to a forensic laboratory and posed direct questions in relation to that evidence. It was for the forensic scientist dealing with the evidence, not the police, to decide which specific tests or techniques would be most suitable for each individual item in order to answer those questions. In the interests of practicality, there may have been discussions prior to the submission regarding the suitability of the item for testing, for example, was it too small, too damaged, too contaminated? etc.

There may also have been decisions to be made in relation to the consequence of the process; some techniques were more destructive than others and permission might have to have been given by the SIO for a destructive technique to be used. In a major crime investigation, collected evidence might have been discussed at a forensic case conference whereby the police, normally the Crime Scene Manager and the SIO or their representative would have met with forensic scientists to discuss the priority order for the submission of evidence and the suitability of items to be submitted. At this stage, niche forensic techniques that may be required may also have been decided on.

OBI-Q6 Were any of the tests and techniques available between 1 September 1997 and 15 August 1998 believed to be unreliable at the time, but have subsequently proved to be reliable?

- 6.37 There are no tests or techniques involved in the recovery and identification of component parts and IED's in the period concerned that were thought to be unreliable at the time, but are now proven reliable.

OBI-Q7 Were any of the tests and techniques available between 1 September 1997 and 15 August 1998 believed to be reliable at the time, but have subsequently proved to be unreliable?

- 6.38 There are no other tests or techniques involved in the recovery and identification of component parts and IED's in the period concerned that were thought to be reliable at the time but are now proven unreliable. It should be noted that, with the exception of the use of modern surveying equipment such as LiDAR, which technically forms no part of the tests or techniques to identify and compare component parts and IED's, the methods used in Omagh in 1998 are no different to those being taught and used in the United Kingdom today.

Explosive Devices Summary

- 6.39 Improvised Explosive Devices are amongst the most indiscriminate and powerful weapons of offence a human can construct. If built 'correctly', something of a relatively small size is capable of causing enormous damage to both infrastructure and innocent people going about their daily lives. Consequently, bomb scenes present substantial additional challenges to investigators and forensic scientists ranging from immediate health and safety issues, sheer quantity of material required to be collected and examined and, in the case of fatal bombings, dealing with human remains.

- 6.40 Explosive devices can vary from relatively simple to elaborately complex in design however, they must all contain the five required component parts. Generally speaking, there is a correlation between intricacy and successful function with the chances of the device failing increasing the more complicated the design becomes. It can also be demonstrated that two bombs of the same design, built by two different people can be discriminated from one another owing to the specific components used in the construction and the techniques used by the individuals to join all the required components together, creating what is often referred to as a “Bomb makers signature”.

7. Fingerprints

Professional background of Kevin Kershaw

- 7.1 *Kevin Kershaw has over 46 years' experience in the examination and reporting of fingerprint and associated evidence – mainly with the Greater Manchester (GMP), and Metropolitan Police (MPS) Forces and latterly as an independent consultant.*
- 7.2 *From 2002 to 2012, Kevin was Head of Forensic Identification Services for (GMP) including Fingerprints, Footwear, DNA, exhibit submissions to, and services provided by forensic laboratories, Digital services, and forensic intelligence management. He was appointed Chair of the ACPO National Fingerprint Training Group, creating the first national fingerprint training programme - which became the blueprint for other forensic training courses delivered within UK policing. He also assisted in the development of Fingerprint foundation degrees at Durham and Teesside Universities*
- 7.3 *In 2007, Kevin was seconded by the Home Office/UK Police Service to consider ways of improving delivery of police forensic services nationally, producing a report 'Organisation and Structure of Police Forensic Services' on the benefits of collaborative working within forensics across the UK. In 2008 he was presented with the Lewis Minshall award for his contribution to the development of the fingerprint profession.*
- 7.4 *Since 2012, Kevin has worked as an independent consultant both in the UK and overseas – mainly in fragile and conflict affected States, on behalf of the UK, US and several European governments.*

*More details of his CV are included at **Annex A**.*

Brief Introduction to Fingerprints

- 7.5 It has long been recognised that it is possible to identify someone from the fingerprints they can leave behind on surfaces which they have touched. This is because no two people – not even identical twins, have ever been found to have identical fingerprints. They were first thought to have been used to help solve crime in the late 19th century⁴⁵ and were adopted as the primary method of personal identification used by the police and other Government agencies in the UK in 1901.

⁴⁵ INQ038311 *Science Against Crime* by S Kind & M Overman (pages 18,19). Published 1972 by Aidus Books Ltd

- 7.6 Fingerprints consist of a series of lines (or ridges) that arch, loop or whorl within a print, and it is these features, and some of the finer detail within them – such as the positioning of sweat pores, that define someone’s fingerprint. Fingerprints are made of sweat secreted through these pores, mixed with oils and salt from the skin and other parts of the body that the hands may touch, as well as any environmental grime that collects on the skin’s surface. Fingerprints are often invisible to the naked eye and need enhancing – either chemically or physically, before they can be seen, collected and compared.
- 7.7 There are basically two types of fingerprint that will be referred to here:
- fingerprints that have been taken from an individual at point of arrest to establish their identity, and
 - fingerprints recovered from a crime scene, incident or event usually by a CSI (SOCO)

Fingerprints from Individuals

- 7.8 These are inked impressions of all 10 digits which have been rolled onto a sheet of clean paper at a custody office. In more serious cases – such as burglary, rape and murder, impressions of the palms of both hands would also have been taken. And much more comprehensive sets of fingerprints would be taken for Terrorist and Counter-Terrorist (TACT) offences.

Crime Scene Fingerprints

- 7.9 These are fingerprints that are recovered from crime scenes, usually by a CSI or other specialist trained specifically in fingerprint recovery. At the material time, there were several techniques used to help visualize and recover fingerprints at crime scenes, including photography, powdering, and powdering and lifting. But there were many situations where a fingerprint was suspected on an item but not always visible, or more detailed work was required. In these circumstances, the CSI would tend to send whole items – sometimes small (eg. a piece of paper or plastic bag), sometimes large (including doors and window frames), to a fingerprint enhancement laboratory so that a wider range of physical and chemical enhancement techniques could be deployed on them.
- 7.10 Fingerprints recovered from crime scenes fall into the following categories:
- Latent fingerprints** – these are essentially marks made by sweat on the summits of the ridges of a fingerprint which can be left on any surface which is able to retain them, or on a porous surface - such as paper, cardboard or untreated wood, into which sweat marks can be absorbed. They are invisible

to the naked eye and therefore need to be treated either by applying a range of fingerprint powders - which adhere to the sweat mark, or by application of a chemical – predominantly, ninhydrin, which will react with constituents of the sweat and render the marks visible.

Additionally, a latent fingerprint can be made more visible to the naked eye by the use of light sources such as ultra violet, and laser – available at least to larger police forces at the time. These non-destructive methods will also require the use of specialist photography to capture and provide a permanent record of fingerprints enhanced in this way.

Patent fingerprints – these fingerprints are made when the surface of the fingerprint has a contaminant on it such as oil, paint, blood, butter, mud etc. In these circumstances, the fingerprint is visible to the naked eye and would be recorded on the substrate as found. In some circumstances it is possible to improve a patent fingerprint and/or reveal more detail in it by applying fingerprint powders or chemicals as above. Any decision to use such further techniques on a patent fingerprint would be made in consultation with a fingerprint chemical enhancement specialist.

Indented fingerprints – as the term suggests, these are fingerprints which are made by the finger touching a soft substrate which is capable of retaining an indentation. Such substrates include, for example, uncured paint on a surface, putty or explosives substances, and the adhesive on sticky tape - particularly insulated electrical tape and packaging tape, which can yield significant indented fingerprints.

As with patent fingerprints, indented prints can be enhanced or improved by the application of suitable powders and chemicals when, again, reference would be made to a fingerprint chemical enhancement specialist.

- 7.11 Fingerprint from both individuals and crime scenes were ultimately submitted to the Force Fingerprint Bureau for processing and comparison. In the case of crime scene prints, they may have gone via the fingerprint enhancement laboratory first to ensure that all prints are found and have been enhanced as necessary to provide the maximum amount of information for comparison.

The Fingerprint Assessment and Comparison Process

- 7.12 There were four distinct processes applied to fingerprint work, namely:

Assessments of prints submitted to fingerprint bureaux for decisions about the extent to which a mark contained sufficient detail for direct comparison with

named suspects, and/or searching against marks held on databases or other collections. If suitable for comparison only, the mark could be compared against prints from a named suspect, but, if sufficient detail was present in it, it could also or alternatively be compared against a database.

Comparisons between two fingerprints to determine if they have been made by the same person. Such comparisons might involve:

- inked fingerprint against inked fingerprint – for example for the purpose of confirming identity at point of arrest
- inked fingerprint against crime scene mark – for identifying or eliminating potential offenders or for intelligence purposes particularly in terrorist related cases
- fingerprints recovered from two crime scenes – to link scenes and events and build composite sets of prints of unknown people, and
- fingerprints from a deceased person to one on a personal possession of a missing person – for example for identifications in mass fatalities

Searching of fingerprints on fingerprint databases held by the police - to establish an identification. As above, these can be:

- inked fingerprint against inked fingerprint – generally applied to new prisoners to establish if they already have a criminal record or to create a new one
- crime scene fingerprints against inked fingerprints, where the examiner will have to try to work out which finger made the crime scene mark
- crime scene fingerprint against fingerprints from other crime scenes – to see if they are linked. This is particularly relevant for linking terrorist incidents or events and individuals.

Fingerprint identification and verification as above, these can involve:

- inked fingerprint to inked fingerprint for maintaining Criminal Records, for example to establish whether a suspect is a known offender, or a new one
- inked fingerprint to a crime scene fingerprint either by direct comparison with a suspect's fingerprints or with a crime scene fingerprint where the

identity of the person who made it has already been established. If at the comparison or search stage an identification was made, then this would be verified/validated by another fingerprint expert.

Practitioner competence

- 7.13 Historically, fingerprints, and crime scene investigation, were predominantly police in-house resources. Up until the mid to late 1970's, the majority of fingerprint practitioners were police officers seconded into this specialist area, however with increasing use of fingerprints to investigate and detect crime, many police forces moved to recruiting non-warranted officers (civilians) to support the demand and release warranted officers to operational duties.
- 7.14 The necessary training to achieve an acceptable level of practitioner competence to be considered an expert was delivered via in-house training, mentoring, and assessment over a five-year period. Some police forces such as West Yorkshire Police (WYP), elected to train and then assess their trainees in-house and grant "Expert" status based upon their own criteria and judgement once the five-year training period was completed. Other police forces, such as Greater Manchester Police (GMP) would assess their trainees at the completion of their five years in-house training, and if successful, the trainee would be sent to New Scotland Yard (NSY) to undergo a two-week independent assessment by NSY senior practitioners/training officers.
- 7.15 Once a trainee was deemed competent by either an in-house or external independent assessment, the Chief Constable of the respective police force could then make a request to the UK Home Office that the officer should be enrolled onto the "*National Register of Police and Government Agencies Fingerprint Experts*". Once the officer was registered, he/she was then granted permission to offer expert opinion on fingerprint-related matters at court.

OBI-Q5a Overview of each test and technique that was available to the UK State between 1 September 1997 and 15 August 1998 for use in police investigations

- 7.16 **Techniques commonly used for visualising and recovering fingerprints at crime scenes** would have been as follows:

Photography

- 7.17 If a fingerprint at a crime scene was obvious or patent, and easy to see, then it would have been photographed *in situ* with a label nearby for reference purposes. The photograph would then be submitted to the Fingerprint Bureau.

Powdering

- 7.18 Many fingerprints found at crime scenes are marks made in sweat and, on their own, are not easy to see. However, when dusted lightly with black or white powder – to provide maximum contrast with the surface they are on, they become highly visible and can then be photographed as above and, again, sent on to the Fingerprint Bureau.

An alternative method for the visualisation and recovery of latent fingerprints was the 'Lifting' technique. This involved first visualizing latent fingerprints by applying black, white or aluminium powder to them, and then carefully placing a clear adhesive tape strip on top onto which the imprint was lifted, and then applying the lift to a contrasting background – either white card for black or aluminium powder lifts, or black card for white ones. Police fingerprint crime scene and laboratory specialists generally selected their own preferred techniques as all were (and still are) effective for the purpose. In connection with this, PSNI have asserted, by way of observation, that the RUC preferred to use black powder followed by the lifting technique and therefore with no requirement for photography.⁴⁶

Aluminum powdering and lifting

- 7.19 This technique is similar to using black and white powders except that this powder is silvery grey in colour. Dusting is followed by the application of low tack adhesive tape to the print which enables it to be lifted off the surface of whatever it had been made on and then stuck down onto a clear acetate sheet for protection. The acetate sheet is then labelled with details of the precise original location of the mark and given a unique reference number by which it can later be identified. Finally, it is photographed and then sent on to the Fingerprint Bureau for processing and comparison.
- 7.20 Many of the 40 Fingerprint Bureaux in existence at the material time had the benefit of an in-house fingerprint enhancement laboratory. These were able to provide a wider range of techniques for enhancing marks and therefore ensure that the maximum amount of information could be extracted from them.

Techniques used in Fingerprint Enhancement Laboratories

- 7.21 The precise technique selected for use on a particular item depended on whether this had a porous or non-porous surface. Porous surfaces included paper, cardboard and wooden items. Examples of non-porous ones would

⁴⁶ INQ041423

include glass, ceramics, plastic bags, metal – for example firearms, and explosives. Two of the most commonly used laboratory based techniques were Ninhydrin – on porous surfaces, and Superglue (cyanoacrylate) – on non-porous ones.

Ninhydrin

- 7.22 Ninhydrin is a chemical which reacts with a constituent of sweat to produce a bright pinkish-purple colour. It is therefore capable of turning a colourless/invisible fingerprint into a bright purple one which can then be photographed for a permanent record. It is used on porous surfaces such as paper as described above.

Superglue

- 7.23 Exposing non-porous items, such as plastic bags and glass, to fumes emanating from a source of Superglue (cyanoacrylate) would reveal white fingerprints on the items from polymerisation of the glue.

Other enhancement techniques

- 7.24 Aside from these, there was a raft of **other chemical methods** for developing invisible or latent fingerprints on items on different surfaces which would have been available to police at the material time. They included, for example, Gentian Violet (GV), Physical Developer (PD), Small Particle Reagent (SPR), and Diazafluorene (DFO).⁴⁷ Then there were some more expensive techniques such as Metal Deposition, and treatment with radioactive sulphur dioxide which would therefore only have been available from certain forces, although they would usually be shared for use on more serious incidents.
- 7.25 In addition, although relatively new at the time, a range of **non-destructive light sources** such as Laser and Quasar were starting to be used to help visualize fingerprints. Laser in particular was expensive so, again, was only available from certain laboratories.

Fingerprint Identification

- 7.26 From 1953 to 2001, the fingerprint identification and verification process was underpinned by what was known as the **Sixteen Point Standard**. This essentially meant that when two fingerprints were compared, there had to be a minimum of sixteen points (known as features or characteristics) in the same

⁴⁷ INQ011665 (pages 1,2)

position and sequence relative to each other before an identification could be declared. The two most common features were a ridge ending which falls between two flanking ridges, and a bifurcation – when a single ridge flowing in any direction splits into two ridges like a two-pronged fork, creating a point at which the ridge bifurcates.

- 7.27 In addition, if there were two separate fingerprints from the crime scene that had a minimum of ten features, each in the same position and sequence relative to each other when compared with the fingerprints on the relevant (inked) fingerprint form, then what was known as the **Ten and Ten Rule** could be applied to confirm the identity of the person who made them.

Use of Databases

National and local fingerprint databases

- 7.28 **A National Fingerprint Collection** was established at New Scotland Yard (NSY) in 1901 and, by 1998, this contained the fingerprints of around 4 million criminals. As well as sending sets of fingerprints to NSY for the National Collection, many forces had their own **Local Collection** for local offenders/active criminals as well. This meant that anyone arrested locally could be checked both locally and nationally to see if they had a criminal record.
- 7.29 These databases were paper based and maintained manually using what was known as the *Henry System of Classification*. This used pattern types found on each of the ten fingers as recorded in inked impressions on the fingerprint form, and which were then sub-classified according to the detail apparent within each fingerprint pattern. Fingerprints from crime scenes would be manually searched against inked impressions on the database which was very labour intensive.
- 7.30 In addition, at local level, if an offender had been arrested for a more serious offence such as burglary, arson or murder, a further, more detailed set of inked fingerprints were taken for inclusion on what was known as the **Singles Index**. These prints were classified under the *Batley System of Classification* which provided greater sub-classification of each fingerprint, and therefore better discrimination between fingers, pattern type and features. This represented a more effective tool to allow individual fingerprints from crime scenes to be searched. But it required greater knowledge and skill of the fingerprint examiner – for example, to determine which finger of the person who left the mark had made it, and it could take many hours to complete when literally thousands of manual comparisons might be required for just one search.

With the introduction of automated databases in the UK such as AFRC and NAFIS, police forces became less reliant on this paper-based manual index. PSNI has asserted, by way of observation, that the RUC had abandoned the use of their Singles Index prior to 1995.⁴⁸

Terrorist and Counter Terrorist (TACT) Fingerprints

- 7.31 Over and above the databases mentioned above, any arrestee who was suspected of terrorist offences would have a further set of fingerprints taken known as TACT fingerprints. These prints were even more extensive than those taken for the Singles Index, and included as much detail as possible from each digit and the palm area of each hand. This was to reflect the fact that a significant number of fingerprints recovered from terrorist incidents are incomplete or fragmentary – especially fingerprints on bomb making material. Essentially, the more detail obtained from the TACT fingerprints, the greater the chance of making an identification from any fragmentary fingerprints found.

It appears that the PSNI, and the RUC before them, did not take TACT fingerprints from suspects.⁴⁹ This can be considered a significant gap in their fingerprint strategy as it means that they could conceivably miss important fingerprint detail and thereby the opportunity to identify a potential offender.

Active Files

- 7.32 Active files were databases, mostly in paper format, that specifically contained fingerprints of known active offenders and/or their associates engaged in particular types of serious criminal activity such as organised crime groups, terrorist cells, drugs cartels, and burglary teams. They were built up through intelligence gathering by investigators on specific individuals or groups.
- 7.33 It was common practice to register the fingerprints in active files with the date they were added to ensure any searches made could be audited if a suspect was later identified, or if previous searches had been completed with a negative result. In this way, registration enabled monitoring of individual fingerprint officers in terms of the accuracy of their searching and comparison skills.

PSNI have asserted, by way of observation, that the RUC did not record the date when fingerprints were included in Active Files in 1997/98⁵⁰. This could potentially have given rise to difficulties both with audit and performance management of individual fingerprint officers, and the accuracy of searches

⁴⁸ INQ041423

⁴⁹ INQ039405 (page 5)

⁵⁰ INQ041423

against Active Files where an identification was later made of someone whose imprints had been previously checked.

- 7.34 In practical terms, although there was a range of databases for particular crime types and purposes, if a significant incident occurred, such as a murder or a terrorist offence, reference would be made to all of the databases described above to support the investigation and try to identify those concerned.
- 7.35 If a terrorist incident occurred in a large metropolitan area of Great Britain, then the incident would initially be investigated by the local police force, but then the MPS Terrorist Fingerprint Team at New Scotland Yard (NSY) would take over the whole case and the local force would second their fingerprint experts to NSY for the duration of the investigation. This made good sense as the MPS Terrorist Fingerprint Team was the UK National Hub for terrorist fingerprint work and held Active Files of known terrorists. Custom and practice in respect of this in Northern Ireland is not clear.

PSNI have asserted, by way of observation, that the MPS Terrorist Fingerprint Team at NSY did not take over fingerprint work on terrorist incidents which occurred in Northern Ireland at the material time and were being investigated by the RUC.⁵¹ However, it is not known whether any of the extensive Active Files of terrorists held by the MPS were shared with the RUC. This would have been an excellent source of support to their fingerprint colleagues in Northern Ireland whilst they were investigating both the Omagh and other bombing incidents.

OBI-Q5b. How widely used or established was each test or technique, and were there any limitations on its use?

- 7.36 The most commonly used fingerprint enhancement techniques at the time would have included Ninhydrin and Superglue to the extent that these would have been available in most if not all police forces. Some forces would have had access to a number of the other techniques described, but only a very few to the most expensive techniques such as Metal Deposition and treatment with radioactive sulphur dioxide. Having said that, these would have been made available at least for the most serious cases. Limitations about which techniques to invest in in-house would have been made on cost and likely usage grounds.

⁵¹ INQ041423

PSNI have asserted, by way of observation, that owing to Health and Safety concerns associated with use of radioactive sulphur dioxide, this technique was not used by the RUC at the relevant time.⁵²

- 7.37 From the documents available at the time of writing, it is not clear precisely which fingerprint enhancement techniques might have been available within the RUC in the late 1990s, but it seems almost certain that, as a 'national' force, and with its heavy caseload of serious cases, the Force would have had a fingerprint enhancement laboratory of its own and would have been able to deploy a range of different methods.
- 7.38 Interrogating the various fingerprint databases would have formed an integral part of regular police work – from the most simple to the most complex of cases.

OBI-Q5c. How were these tests and techniques used practically?

- 7.39 There were two distinct areas of police fingerprint-related business – one relating to the processing of fingerprints taken from arrestees, and providing maintenance and support for their local collection of known offenders and the National Criminal Records Office (CRO), and the other - using the examination, comparison and identification of fingerprints in criminal investigations, for example:
- to identify suspects from finger or palm prints they may have left behind at a crime scene
 - to help to establish the sort of activity in which they had been engaged there – for example, climbing in or out of a window, or actively involved in an assault
 - to recognise when a number of crimes had been committed by the same person ie. a serial offender
 - to identify people from their handling of items associated with crime – such as drugs wraps, or bomb components, and
 - to identify unknown people including victims of mass disaster

⁵² INQ041423

OBI-Q5d. What sort of forensic material, and how much was required for reliable use of the tests and techniques?

- 7.40 As we have seen, fingerprints can be made in a variety of materials including, most commonly, the sweat, oils and salt produced by the skin, and any environmental grime to which the hand(s) have been exposed. They can also be made in other substances with which the hands have come into contact such as the blood of victims of assault, the ink in a pen with which the person who left the print may have been writing, or grease from the food they may recently have been eating. These other substances can then provide further links between a perpetrator and their crime.
- 7.41 An average fingerprint contains around 150 ridge features or characteristics. At the relevant time, the Sixteen Point Standard for identification – ie the requirement for a minimum of 16 corresponding features or characteristics between two fingerprints for identification, was still in force, as was the Ten and Ten Rule – namely, the requirement for at least 10 such matching features or characteristics between two separate fingerprints at a crime scene for the source to be identified.

It should be noted, however, that it is possible for a fingerprint to be identified with as few as eight features or characteristics in sequence between two impressions. To this extent it was accepted, prior to the move to the Non Numeric Standard in 2001, that identifications made with a minimum of eight features/characteristics in sequence could be reported to an investigator but to provide intelligence only; they could not be used by the prosecution in evidence as they fell below the Sixteen Point Standard/Ten and Ten Rule. When such an identification was made, official notification relating to this would be sent to the investigator or investigative team. This notification would be clearly marked as being 'insufficient for court purposes'.

Reflecting this, FSNi have asserted, by way of observation, that the RUC applied the Sixteen Point Standard in 1997/98. However, where matches fell short of the 16 points required, they would still have been reported to the investigation team but it would be explicitly stated that such reports were non-evidential – ie. no attempt could have been made to rely upon such results as evidence in court.⁵³

- 7.42 Ultimately, the amount of material required to produce a conclusive result would depend very much on the quality of the print under review, the precise part of the finger or palm involved and the extent to which this contained

⁵³ INQ041423

characteristic features for comparison, and the quality of the suspect's inked fingerprint form available at that time.

- 7.43 It follows that any opportunity to identify a crime scene fingerprint from a search against any available database would be dependent firstly on the offenders' fingerprints being held on that database, and then that the fingerprints held were of a sufficient quality and contained the specific area of the fingerprint (or palmprint) found at the crime scene. This is one of the reasons why, when a suspected terrorist was arrested, a comprehensive set of their fingerprints was taken including as many features and characteristics of the prints as possible – a process which itself could take several hours to complete.

OBI-Q6. Were any of the tests and techniques available between 1 September 1997 and 15 August 1998 believed to be unreliable at the time, but have subsequently proved to be reliable?

- 7.44 As with other aspects of forensic science, there have been technological advances in tests and techniques for fingerprinting over the years, but these are more likely simply to have improved the chances of getting a result than to demonstrate any underlying flaw in any of them.
- 7.45 But what has happened is the emergence of a better understanding of cognitive bias – ie. the tendency for scientific judgements to be influenced by prior knowledge about a case, and the consequent development and implementation of measures to guard against this – see Q7 below.

OBI-Q7. Were there any types of testing or techniques available between 1 September 1997 and 15 August 1998 believed to be reliable at the time, but have subsequently proved to be unreliable?

- 7.46 Issues with fingerprint evidence have related more to practitioner skill and judgement than anything to do with the physical and chemical tests available. For instance, probably the most high-profile failure of fingerprint evidence around the relevant time concerned the misidentification of a thumb print on a bathroom door at the scene of the murder of Marion Ross in Kilmarnock in 1997. This thumb print was said to have been made by Detective Constable Shirley McKie who had been on duty outside the house but who insisted that she had never entered it. McKie was charged with perjury. At her trial, three Scottish fingerprint experts maintained that the thumbprint had been made by McKie, but two American experts said that her thumbprint was markedly different, and she was acquitted. Meanwhile, the man found guilty of

Ross's murder had his conviction quashed on appeal when the judges accepted that the fingerprint evidence was, in general, unreliable.⁵⁴

7.47 Reflecting growing awareness about the risks of cognitive bias – including as this relates to fingerprint examination and analysis, in 2007/8 the author, Kevin Kershaw, worked closely with acknowledged cognitive bias expert, Dr Itiel Droor of Southampton University on the impact of cognitive bias in forensic decision making⁵⁵. This culminated in a series of workshops for fingerprint practitioners across the UK on how such bias could be mitigated or reduced. Over the past 15 years, awareness training and process changes have become commonplace throughout forensics, with interventions in relation to fingerprints including:

- Independent checking and verification of all fingerprint identifications declared
- Establishing an arbitration process for any contentious decisions
- Moving away from hierarchical checking processes which could result in undue pressure being put on more junior practitioners
- Putting a barrier between investigator and practitioner to further reduce any pressure/bias.
- Removing consideration of the context/seriousness of an incident from the process.
- Undertaking regular dip sampling of practitioner decisions to monitor performance and potentially identify any health or competence issues.
- Conducting regular/annual independent competency assessments

7.48 In addition, in 2001 a new, Non-Numeric Standard for fingerprint identification to replace the Sixteen Point Standard was introduced along with a methodology for all fingerprint work known as ACE – V (Analyse, Compare, Evaluate, and Verification). This new approach focused on the quality and uniqueness of fingerprints under review, rather than simply the number of features/characteristics being compared.

⁵⁴ INQ038266 *The Fingerprint Inquiry Report/Scotland 2011* ISBN: 978-0-85759-002-2 (ch 1, page 31)

⁵⁵ INQ038232 *Contextual information renders experts vulnerable to making erroneous identifications – Itiel E Droor, David Charlton, Ailsa E Peron Forensic Science International 156 (2006) (pages 74-78)*

- 7.49 In combination, these measures have undoubtedly improved the skill and quality of judgement of fingerprint experts, and the extent to which their opinions are routinely checked, and therefore the soundness of their evidence.

Fingerprints Summary

- 7.50 Fingerprints have been in routine use in the UK since the beginning of the 20th Century as a main means of establishing personal identification.

- 7.51 A wide range of physical and chemical techniques for enhancing such prints – which are often invisible to the naked eye, were available at the material time, and there were both a national, and local databases to help identify the source of unknown prints. *In relation to Northern Ireland, apparently the RUC did not take more detailed (TACT) fingerprints from suspects in terrorist cases to ensure as much detail as possible had been captured. It is therefore conceivable that some fingerprint detail may have been missed, and with it the opportunity to make identifications.*

There is nothing currently to suggest that there was any interaction between the RUC and the MPS anti-terrorist fingerprint team. This seems strange given the number and severity of terrorist incidents in Northern Ireland at the material time, the pressure the Force must have been under, and the useful knowledge and expertise of the MPS in this field.

Also of critical importance was the skill and expertise of the fingerprint examiner.

- 7.52 Cognitive bias became of increasing concern in the late 1990s and this came to a head with the misidentification of a fingerprint said to have been made by a police officer, Shirley McKie. As a result, a great deal of work was carried out in the 2000s by Kevin Kershaw in conjunction with a leading academic expert on bias, and a range of measures put in place to prevent it.

8. DNA Profiling

Professional background of Dr Philip Avenell

- 8.1 *Dr Philip Avenell is a highly experienced forensic biologist who has successfully led a number of large, convoluted forensic investigations involving complex DNA analysis and interpretation and combining this with other types of forensic evidence. Philip has also occupied senior laboratory roles in the management of forensic science casework, quality management and research and development.*

*More details of his CV are included in **Annex A**.*

Brief Introduction to DNA Profiling

- 8.2 DNA is a complex molecule found in almost every cell in the human body. It carries our genetic material which determines everything about us from our hair and eye colour to the structure of our body and its internal workings. The DNA throughout our bodies is the same, that is the DNA in our white blood cells is the same as the DNA in our skin cells or cells within our saliva. We know that, while our DNA codes this vital information for life, large amounts of it appear to have no function in making us who we are. This is referred to as 'junk DNA', which is also present and identical in all our cells.
- 8.3 Forensic DNA profiling involves obtaining a DNA profile from a body fluid stain associated with a crime – such as blood, semen, or saliva or, from the early 2000's onwards (as tests improved and techniques became more sensitive), 'touch DNA' from skin cell traces left on touched items, and then comparing this with DNA from reference samples taken from suspects or other individuals in the case. If the crime stain and reference profile do not match, then the DNA in the crime stain could not have come from that individual. However, if they do match, then the DNA in the crime stain could have come from them.
- 8.4 Except in the case of identical twins, no two people will have the same DNA profile. However, as DNA is inherited from our parents, the more closely related individuals are, the more likely they are to have components in their DNA profile in common.
- 8.5 DNA profiling used in forensic investigations utilises the 'junk DNA' described above and originates from the discovery of hyper-variable regions within it first identified by Professor Alec Jeffries in the early 1980's^{56, 57}. Professor Jeffries

⁵⁶ INQ038233 Jeffreys, A.J., Wilson, V. & Thein, S.L. Hypervariable "minisatellite" regions in human DNA. *Nature* **314**, (pages 67-73) 1985

⁵⁷ INQ038243 Jeffreys, A.J., Wilson, V. & Thein, S.L. Individual specific 'fingerprints' of human DNA. *Nature* **316**, (pages 76-79) 1985

discovered that, whilst showing similarities between individuals, these hyper variable regions also showed differences, and that these similarities and differences could be used to discriminate between specific individuals as potential sources of DNA in body fluids and tissues left behind at the scene of a crime. This led to the selection of a number of such regions of DNA which could be used for forensic purposes – for example, to link DNA left at a crime scene or on a victim of crime with a specific individual from whom it could have come.

- 8.6 The regions themselves used in forensic testing are referred to as Short Tandem Repeats (STR) – distinct areas of DNA where a specific short sequence of genetic code is repeated a number of times, this number varying within a defined range specific to each region identified. For each region the frequency of observing a specific number of repeats within a population can be determined and, as explained later, forms the basis of determining how common a DNA profile may be within a population.
- 8.7 In the early 1990s, only a few regions of DNA had been identified as suitable in forensic testing. This, combined with relatively primitive testing and analysis techniques meant that, whilst DNA profiling represented a significant advancement over blood grouping, its capabilities were limited. Over time, as more areas were identified and included, and better testing techniques and equipment for analysis became available, DNA profiling advanced to become the highly useful and accurate technique we have today⁵⁸.
- 8.8 Whilst there is variation in the number of repeats within each of the regions of DNA used in DNA profiling, there is still only a finite number – for example, between 8 and 17 repeats, with some repeats seen more commonly in a population than others. Therefore, the fewer regions we look at, or in the case of very small amounts of DNA, the fewer regions in a crime sample we are able to detect (commonly referred to as a partial DNA profile), the more people there will be within a population that could have that DNA profile. Put another way, the more likely it is that the DNA profile will match an individual just by chance.
- 8.9 Reflecting this, DNA evidence is always presented as the probability of seeing the specific DNA profile (or partial DNA profile), obtained from the crime stain within an individual in a given population of people. This then allows an assessment to be made as to how likely it is that the DNA in the crime stain has come from the matching individual rather than someone else selected at random from that population.

⁵⁸ INQ035720 Butler, J. M. (2010). *Fundamentals of forensic DNA typing*. Elsevier Academic Press (pages 1-18, 43-78)

History of the Development of DNA Profiling Tests

- 8.10 Prior to the introduction of modern DNA profiling techniques, which started in the early 1990's, a number of methods were being used in an attempt to identify from whom a body fluid detected on a victim or suspect or at the scene of a crime, could have come. These methods ranged from the ABO blood grouping system, to detecting different forms of the same enzymes such as Erythrocyte Acid Phosphatase (EAP), and Phosphoglucomutase (PGM) and the protein molecule, Haptoglobin (Hp). However, all these techniques required relatively large volumes of testing material, produced results with little power to discriminate between individuals ('discriminating power'), and only tended to last for a few weeks.
- 8.11 The first DNA profiling techniques targeted multiple regions of DNA simultaneously, producing a result which has often been likened to a supermarket bar code. This was superseded by a technique which targeted a series of single regions of DNA which was useful as it required rather less DNA starting material. But a real breakthrough came in the early 1990s when it became possible to increase, or 'amplify', the amount of DNA in a sample by copying it many times over prior to analysis because this dramatically reduced the amount of DNA required from a sample to produce a result. The best known of these techniques focused on the Human Leukocyte Antigen (HLA) DQa, and was used for a number of years in the early and mid-1990's alongside the development of more sophisticated techniques – all of which used, and still continue to use Polymerase Chain Reaction (PCR)⁵⁹ to create the multiple copies of DNA.
- 8.12 In the mid-1990's came the development of **Short Tandem Repeat (STR)** analysis which could simultaneously test for several STR DNA regions at once. This revolutionised forensic DNA profiling because it was both very sensitive (through the use of PCR) and relatively discriminating; it is the basis for all modern techniques used today. The first version of the technique – known as Quad 1, was introduced within UK laboratories in 1994. This examined 4 specific STR locations and was capable of a discrimination power of around 1 in 10,000 individuals⁶⁰. Quad 1 was only used for a relatively short period before being phased out in favour of newer, more powerful techniques.

⁵⁹ INQ014956 (whole)

⁶⁰ INQ014934, INQ014943 (whole)

- 8.13 In particular, by 1995 the **Second Generation Multiplex (SGM)** technique had been developed and rolled out in UK laboratories. This looked at 6 STR regions (plus one which indicated the gender of the donor) and was capable of a discrimination power in the order of 1 in 50 million. With its much greater discrimination, it led to the development and use of the first DNA databases, where collections of DNA reference profiles from known individuals and unidentified crime stain profiles were then stored and used in searches for links between individuals and crimes.
- 8.14 Whilst highly sensitive for its time - compared with previous DNA techniques, and blood grouping and enzyme polymorphism techniques before them, SGM still required around 2 nanograms (ng) of DNA to obtain a result – typically meaning that a visible body fluid stain such as blood, semen or saliva was required, and samples such as touch DNA were very rarely considered. Whilst other techniques may have still been available, SGM was the most commonly used and best regarded technique at the time of the Omagh bombings⁶¹.
- 8.15 It was not until 1999 that the introduction of the next technique - **SGM plus**, occurred – firstly in England and Wales, with the technique being rolled out in Northern Ireland in 2001. This enabled the analysis of 10 STR regions (plus a gender indicator) in a single multiplex kit and provided a discrimination power in the order of 1 in a billion individuals. The kits also saw better resistance to inhibitors, and a large increase in sensitivity, now able to detect DNA from samples containing as little as 0.4ng of DNA – typically stains barely visible to the human naked eye and increasingly including touch DNA samples. Even so, they were still nowhere near as sensitive as modern DNA profiling techniques. SGM plus was first used by the FSS in England and Wales and then rapidly introduced into other laboratories throughout the UK.
- 8.16 It was also in 1999 that the FSS introduced the technique known as **Low Copy Number (LCN)** DNA profiling. This development involved increasing the number of PCR amplification cycles referred to earlier to increase the amount of starting material, and therefore the sensitivity of the test. This enabled analysis of samples containing as little as 0.1ng (or 100 picograms (pg)) of DNA – amounts not visible to human naked eye.

⁶¹ INQ041934 (whole)

OBI-Q5a. Overview of each DNA test and technique available to the UK State between 1 September 1997 and 15 August 1998 for use in police investigations

- 8.17 Against the background of all the above – SGM was the main DNA profiling technique in general use in the UK – *including in Northern Ireland*,⁶² at the relevant time. All other techniques which had been used up to this point had been generally phased out in favour of it, although they still remained in use in some parts of the world, and for paternity and mass disaster identification.
- 8.18 But DNA profiling is not just about the analysis of DNA itself, but all the critical processes that lead up to this, and necessary deliberations about what the results are likely to mean in the context of specific case circumstances that follow.

The DNA Testing Process

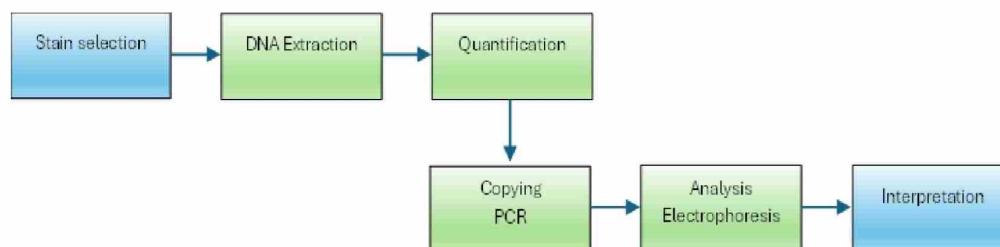
- 8.19 The DNA testing process itself involves four distinct sequential steps as illustrated as part of the overall process in Figure 3 below. Firstly, the DNA in the sample selected must be **extracted** to remove cell debris or background material which could otherwise interfere with the profiling process. This was often a problem with early techniques.
- 8.20 The second stage involves **quantifying**, or measuring, how much DNA is present in the extracted sample. It is important to know this, as too little or too much DNA and the next stage in the process would not work. Again, early quantifications were often inaccurate, and so having to re-test samples was quite common when samples did not yield results as expected.
- 8.21 The third stage of the process starts to target only the (hyper-variable) areas of DNA of interest for analysis, **copying** them a number of times to ensure there is sufficient DNA to analyse. This process is known as Polymerase Chain Reaction (PCR). During the period 1997/98, all DNA processing was carried out using 28 cycles of copying. (While subsequent research within the FSS showed how increasing the number of cycles to 34 in the LCN technique referred to above, enabled results to be produced from samples containing much smaller amounts of DNA, this was not available in 1997/98).
- 8.22 The fourth and final stage in the process involves **analysis** of the DNA. The technique used for this was Electrophoresis - which is a form of chromatography whereby the components of interest in the DNA extract were

⁶² INQ011657 (page 1)

separated from one another, and their presence detected by virtue of their respective lengths. These lengths are then converted into the numbers which are commonly seen in DNA reports and are the basis for comparison and conclusions as to whether or not someone could have contributed to the DNA detected in a sample.

- 8.23 The results of the analysis are then passed to the lead biologist in the case for **interpretation**. They would confirm the components in the DNA profile (or partial profile) which had been detected in, for example, a sample from a victim or crime scene, and compare it with any reference DNA profiles from suspects which might be available. Alternatively, where there were no suspects in the case, they would arrange for the National DNA Database (NDNAD) to be interrogated to see if the crime stain DNA matched that of any individuals, or recovered from any other crime scenes, recorded on the Database.

Figure 3. Summary of all stages of the DNA profiling process from stain selection to interpretation of the results and comparison with reference profiles.



OBI-Q5b. How widely used or established was each DNA test or technique, and were there any limitations on its use?

- 8.24 Such was the demand for DNA testing at the relevant time that forensic biology departments were expanding in an effort to train and develop more scientists in the use of the techniques, and how to assess and interpret the results in specific case contexts. This was accompanied by development of modern laboratory methods - such as batch processing, and introduction of good laboratory practices and streamlined workflows. All of this enabled samples to be processed simultaneously and continuously, and therefore more quickly.
- 8.25 So, by 1997/98, SGM DNA profiling was being widely used within forensic laboratories throughout the UK for cases where sufficient body fluid material had been identified.
- 8.26 The introduction of DNA profiling databases to store both reference DNA profiles, and DNA profiles from crime stains where the source had not been

identified, also started around 1995. In the UK, this involved the establishment of the National DNA Database (NDNAD) for England and Wales as well as separate smaller databases for Scotland and Northern Ireland. Whilst separate, both the Scottish and Northern Irish databases fed into the NDNAD which therefore acted as a central resource for searching DNA results obtained and loaded throughout the UK. The results of all matches were fed back according to strict protocols.⁶³ *It appears that, at the relevant time, the Republic of Ireland did not have a database of DNA from known individuals, although it did have an informal one containing crime related material. It is not clear whether and to what extent there was any interaction between this and FSANI⁶⁴.*

- 8.27 Limitations on the use of DNA profiling at the time mainly related to the (relatively large) size of stain required to obtain a result, and the cost of testing and therefore the extent to which DNA tests were commissioned. It was less often used on smaller or speculative sampling of areas thought, rather than visually seen, to contain DNA, and in anything other than the more serious or difficult of cases.
- 8.28 The techniques used to search for, and identify suitable body fluids, have changed little over the years since their first introduction in the 1960's and 1970's. This would not have mattered in the late 1990s because of the still relatively large size of stain required to produce a DNA profile at the time, although it is a very significant consideration nowadays.
- 8.29 Similarly, in the early years of DNA profiling, little was understood about the potential for DNA to be transferred between one item and another at the crime scene, or prior to submission of items to the laboratory, and therefore the concept of contamination within DNA testing. This meant that few, if any precautions were taken to prevent it. For example, the use of personal protective equipment (PPE) to prevent contamination of items by someone handling them was only rarely considered – the focus being on protecting the scientist from the item rather than the other way round. Whilst some precautions would have been taken within the laboratory, and especially if textile fibre examinations were also being conducted in the case, these were not as stringent as those which began to be implemented around the late 1990's/early 2000's as the increasingly sensitive techniques of SGM Plus and LCN started to be implemented.

⁶³ INQ014976 (whole)

⁶⁴ INQ041292 (page 5)

OBI-Q5c. How were these tests or techniques used practically?

- 8.30 By the late 1990s, DNA profiling had become established as one of the central tools within any forensic biology department. It was particularly powerful when used in combination with Blood Pattern Analysis (BPA) or semen staining identification for example. The DNA would help clarify from whom the blood or semen within patterns or distributions could have come and therefore assist with activity or timing as to how or when that body fluid could have been deposited. It was also very useful (in combination with the NDNAD or a pool of likely suspects) in helping to identify those individuals who might be of particular interest to the investigation team.
- 8.31 Against this background, and particularly with the increasing recognition that the technique was becoming more sensitive and detecting smaller amounts of DNA, it was able to be used in the late 1990s to early 2000s in a variety of ways in criminal investigations. These included, for example:
- to investigate potential links between a suspected offender and a victim of crime or a crime scene – including on handles of weapons such as knives that could have resulted in an injury to the person who used them. It was also being used in other high profile areas such as crime scenes associated with bombing offences – including locations where components of explosive devices had been stored and/or assembled prior to placement and detonation
 - to provide information through which an unknown offender could be identified – either via the National DNA Database, or a ‘mass screening’ of a section of the local population
 - to distinguish who was more likely to have been actively involved in an attack involving more than one potential offender
 - to search for DNA from the wearer – particularly on clothing items left behind or abandoned after the commission of a crime or recovered from a site known to be associated with offenders
- 8.32 But whatever the circumstances, within the laboratory the lead biologist for the case would be working to the strategy agreed with the police Senior Investigating Officer, including any overlaps with other forensic scientists involved in the case. It would be his or her responsibility to assess all items submitted for examination, identify any potentially useful DNA-containing material on them – such as blood and other body fluids, and ultimately determine their suitability for DNA profiling. At the relevant time, decisions would be influenced by the amount of body fluid stain available to sample, how

it was distributed on the item, the context of the item within the circumstances of the case, and the type of case and therefore justification for the time and cost of the testing.

- 8.33 Traditionally, it had been typical for this same scientist to personally carry out all or most aspects of the testing in a case themselves – from selecting a stain to carrying out the test and reporting the result. However, the more complex and time-consuming processes became, and the greater the number of tests required to be carried out, the more that different parts of the process were shared between different forensic scientists, and this was especially true when DNA profiling was introduced. In the end, distinct teams were established to focus solely on DNA testing itself. Specific team members would receive samples from the lead biologist, processing them as appropriate to get a DNA result, and then feeding those results directly back to the lead biologist who would run appropriate quality checks and report the result in the context of the case to which it related. This separation of duties meant that DNA testing staff could focus on the testing process itself and not be distracted by other aspects of casework which might otherwise slow down the rate at which results could be produced. They could also ensure the continuing development and introduction of new techniques and processes to increase the capability and use of DNA testing.

OBI-Q5d. What sort of forensic material, and how much was required for reliable use of the tests and techniques?

- 8.34 The SGM Profiling technique in use in the UK at the material time required approximately 2ng of input DNA in order to get a suitable DNA profile which could be used for comparison. This DNA could be derived from any of the more common body fluids such as blood, semen and saliva, or tissue samples such as a dislodged tooth, or clump of hair – but only if these had been forced or pulled out as opposed to having fallen out naturally.
- 8.35 To put this in context, a single human cell – of which there are of the order of 37 trillion in the human body, contains roughly 6 picograms (pg) of DNA – equivalent to around 0.006ng. Therefore, providing all cells in a sample contain ideal DNA for testing (not always the case as some may be degraded), and extraction processes are 100% efficient (which was rarely the case with earlier DNA testing protocols), it would require around 335 cells in order to obtain a DNA profile from a sample. In reality this meant that, to obtain a usable DNA profile at this time, a stain would need to be of a body fluid such as blood, semen or saliva, and clearly visible to the naked eye. Therefore, at the time of the Omagh bombing, swabbing an item such as a car door handle for touch DNA, would not have been considered a realistic option.

OBI-Q6. Were there any types of testing or techniques available between 1 September 1997 and 15 August 1998 believed to be unreliable at the time, but have subsequently proven to be reliable?

- 8.36 The SGM profiling technique used at this time was considered a reliable and accurate testing method, and remains so to this day. The methodology itself was robust and contained sufficient internal quality controls – such as running samples of known DNA and blank samples with no DNA in them, alongside the casework ones, and ensuring key stages in the process were witnessed or checked by a second scientist, to give confidence that the results of the test were accurate and had been assessed properly.
- 8.37 Around this time, many laboratories were starting to look to attain accreditation to international standards in order to demonstrate that the tests they were carrying out met those standards. However, accreditation was in its early stages and not enforced for those DNA providers loading samples to the NDNAD until the mid-2000's.
- 8.38 Any issues with DNA profiling tend to arise around the interpretation of the results obtained, rather than the results themselves.
- 8.39 These issues are two-fold and stem from 2 main questions:
- 'Did the DNA all come from one and the same person?' or put another way 'is this the correct DNA profile from this sample?' or could it conceivably represent a mixture of DNA from more than one person?'
 - 'Could the DNA have arisen as the result of some form of contamination?' or, put another way, 'was the DNA deposited at the time of, or prior to the crime, or could it have been deposited after the crime had been committed as a result of some flaw in the collection, storage or processing of the item/DNA sample?'
- 8.40 There has been a great deal of debate about these questions since the introduction of STR DNA profiling in 1995, which was given added force following the arrival of SGM Plus and LCN DNA profiling in 1999 – much of this resulting from the Omagh trials in early 2002 (see OBI Q7 below).
- 8.41 However, because of the lack of sensitivity of the SGM profiling technique used in 1995-1999, these considerations were not as significant then as they became after 1999 and are in the modern highly sensitive DNA profiling used today. This is because such relatively significant quantities of DNA were required to obtain a result, and the interpretation of the results was relatively robust, with results only reported which were clearly distinct from a baseline.

No significant issues were identified or recognised within the industry until the introduction of the much more sensitive DNA profiling techniques in the early 2000's.

OBI-Q7. Were there any types of testing or techniques available between 1 September 1997 and 15 August 1998 believed to be reliable at the time, but have subsequently proved to be unreliable?

- 8.42 Whilst not directly relevant to the time in question, LCN DNA profiling was used in the Omagh bombing investigation by the FSS from around 1999 onwards. At the time, the technique was considered suitable for use in casework. It was claimed by the scientist involved that the technique had been assessed as appropriate and had been validated for use in casework. However, defence scientists working in the case of *The Queen vs Sean Hoey* argued this was not the case⁶⁵. They demonstrated that at the time there was no international adoption of the technique and no agreed validation either, both in contrast to the use of SGM Plus DNA profiling which was widely used internationally and had agreed international validation guidelines.
- 8.43 In addition, the ruling in this case also highlighted significant issues regarding the sensitivity of the technique, and the lack of anti-contamination measures in relation to exhibit handling and exhibit recovery at the time of the Omagh bombing, throwing further doubt on the validity of any results obtained using this technique. As a result, this trial and the credibility of the LCN DNA profiling technique in general became an issue.
- 8.44 Given these findings and the challenges to the early use of LCN DNA profiling, the technique underwent significant research and validation to ensure the suitability of results. A later report, published in 2007, was commissioned by the newly appointed Forensic Science Regulator for England and Wales to look into the reliability of LCN DNA Profiling⁶⁶. This report identified that in the years after the initial launch of LCN DNA profiling by the FSS, two private forensic service providers in England and Wales had recognised the significance of the LCN technique and developed their own techniques capable of achieving the same outcome from such small amounts of DNA, but using slightly different methodologies. These new techniques along with LCN DNA profiling all then started to be referred to in general as Low Template DNA profiling (LTDNA analysis).
- 8.45 In addition, the use of the LCN DNA profiling technique was starting to be adopted internationally and international guidelines were developed for the

⁶⁵ INQ000261 (pages 21, 22)

⁶⁶ INQ011672 (whole)

validation of the technique and interpretation of the results.⁶⁷ By 2002 LCN DNA profiling performed by the FSS⁶⁸ had also been accredited to ISO/IEC 17025 – an international standard developed for testing and calibration processes and first introduced in 1999.⁶⁹ The accreditation process would have demonstrated the suitability of the test to provide accurate and reproducible results within the parameters of the test and requirements of the standard and as determined by independent assessors. Subsequently, the test which had been considered as unreliable in the trial of Sean Hoey and other related incidents at the time, was now recognised as being a valid and appropriate technique – however, concerns still persist about the potential for contamination of exhibits as a result of the lack of anti-contamination procedures originally – as also highlighted in the judgement relating to *The Queen vs Sean Hoey*.⁷⁰

DNA Summary

- 8.46 DNA profiling capabilities have undergone many years of development to reach the levels of sophistication in terms of sensitivity and discriminating power, in the modern DNA testing we know today. Initial techniques based on the STR multiplex DNA testing used today were initially introduced into forensic casework in the early to mid-1990's. By 1997, and during the time of the Omagh bombing, the SGM DNA profiling technique was being widely used across all UK forensic science laboratories. DNA databases had also been established for a number of years and were starting to prove an effective tool for cases where DNA profiles had been obtained but did not match known suspects in the case or no suspect had been identified.
- 8.47 However, DNA profiling at this time still required there to be a significant amount of DNA in a sample, and in the form of a clearly visible body fluid such as blood or saliva, in order to obtain a useable DNA profile that could be used to link a body fluid with a given individual. It would not be until the very late 1990's/early 2000's when more sensitive types of DNA profiling – in the form of the newer SGM Plus DNA test, and high sensitivity techniques such as LCN DNA profiling, that very small quantities of DNA – such as touch DNA, could be successfully sampled and results obtained.

⁶⁷ INQ011672 (section 3.2)

⁶⁸ INQ023731 (whole)

⁶⁹ INQ041350 www.iso.org/ISO-IEC-17025

⁷⁰ INQ000261 (whole)

9. Textile Fibres

Professional background of Professor Roger Robson

- 9.1 *Roger Robson is a leading UK expert on the forensic examination of textile fibres. He has worked in the UK forensic industry for 45 years in both the public and private sectors, specialising in the most complex international criminal cases involving trace evidence, including historic crimes and appeals. As an expert witness he has given testimony in seven countries, lectured internationally, and produced a range of related scientific publications. He has been an active member of various international working groups, professional standards committees, and public enquiries and served on The Forensic Science Regulator's Advisory Council (2009-2019).*
- 9.2 *He is also a Visiting Professor in Forensic Science at the Centre of Crime, Justice & Security, Staffordshire University, and a Fellow, and Past President, of the Chartered Society of Forensic Sciences.*

*More details of his CV are included in **Annex A**.*

Brief Introduction to Textile Fibres

- 9.3 Forensic analysis of textile fibres has played a key role in criminal investigations over several decades – both in the UK and internationally. By the late 1990s, use of textile fibres as a form of associative evidence in large investigations was probably second only to DNA. This was partly because in general terms, fibres are everywhere – in our clothing, in our car seats and in soft furnishings in our homes and those of our friends and family, in our workplaces and places of entertainment, and we will constantly leave behind our own fibres and pick up fibres from others as we go about our daily business. Added to this, there is a huge variety of fibres reflecting advances in manufacturing technology and trends in fashion, and experiments showed that, even with mass produced items, it is relatively uncommon to find fibres from two items that match by chance, or in any number, in the sorts of tests used by forensic scientists.
- 9.4 Fibres can provide primary evidence themselves but also assist in the discovery of other forms of evidence, and help investigators understand the sequence of events at a crime scene, prompting new lines of enquiry for them to pursue.
- 9.5 Textile fibres can be made of a wide variety of materials – natural: eg. cotton, linen and wool, and synthetic: such as acrylic, nylon, and polyester, and blends of these. Synthetic fibres are usually coloured, are manufactured with specific

cross-sections and often contain additives – notably delustrant (a dulling agent), and it is the combination of fibre type, their dimensions, precise colour, and any other inclusions or surface treatments that can provide evidence of a connection between people, places, vehicles and a wide variety of other things.

- 9.6 Fibres in the forensic context do not usually involve whole strands of fibres twisted together to form a yarn, but individual fragments of such strands – generally too small to be seen with the naked eye. These fibre fragments tend to break off clothing, soft furnishings and other fabrics when these are worn or used and can then be transferred to the surfaces of other items with which the wearer or user comes into physical contact.
- 9.7 There are various stages in the process of finding transferred textile fibres which match specific constituents of other items of interest and therefore could have come from them. Initially these involve microscopes to determine what the fibres look like close-up. Then various types of chemical and physical analyses are conducted to determine what the fibres are made of, and more precisely what colour they are and how they have been dyed.
- 9.8 Great care is taken throughout the process to avoid contamination between one item, or one set of fibres, and another and which could compromise findings and conclusions drawn from them. In particular, items are examined on top of clean brown paper, on clean benches, and on different benches and/or in different rooms by different scientists wearing different lab coats and using different equipment – depending on the circumstances. Assumptions tend to be made that anti-contamination procedures were also followed prior to laboratory submission unless there is evidence to the contrary, for example, if two items from different people had been seized by the same police officer.

OBI-Q5a. Overview of each test and technique that was available to the UK State between 1 September 1997 and 15 August 1998 for use in police investigations

- 9.9 Forensic fibres examination and analysis comprised several stages of activity, each stage being integral to the next. These included **recovering fibres** from the surfaces of items to which they had been transferred and, at the same time, taking reference samples of fibres from any items made of fabric, **deciding which fibres to look for** and on what, making an **initial comparison** between reference samples and recovered fibres to identify any individual fibres of potential interest, and then a **more detailed comparison** to see if any of these fibres continue to be indistinguishable from their proposed sources through the full range of tests, and finally, **interpretation and reporting** of results in the context of the case.

Recovering Transferred Fibres and Taking Fibre Reference Samples

- 9.10 As each individual item collected from a crime scene, or a victim or suspects was examined, textile fibres (and other tiny traces) would be recovered from its surfaces by, for example, picking them off with the aid of a microscope, or by sequentially applying sticky tape strips known as 'tapes', 'tapings' or 'tape lifts' to its surfaces. These tapes were then stuck down onto clear plastic sheets and placed in polythene bags for ease of handling and protection from loss or contamination. In addition, around 1995/96, FSANI started to use a simple method to extract fibres from the head hair of suspects. This was important at the time because the FSANI Laboratory in particular was dealing with a large number of "woolly" gloves and balaclavas - often discarded at the scene or left behind in stolen cars⁷¹. The technique involved combing the hair with a comb which had had cotton wool threaded between its teeth. Fibres in the hair became trapped in the cotton wool and could then be easily picked off for closer inspection and comparison.
- 9.11 At the same time as recovering fibres from items, in the case of fabric items, samples of their own constituent fibres would have been taken and mounted on microscope slides. This was to facilitate any comparison with recovered fibres from other items. A note would also have been made about how readily each fabric item shed its constituent fibres because this 'shedability' factor would play an important part in developing a fibre examination strategy for the case.

Deciding which Fibres to Look for and on What

- 9.12 When items had all been examined, it was then possible for the scientist to make informed decisions about which constituent (reference) fibres to target as potential sources when looking amongst recovered fibres picked off or stuck on tapes taken from other items. Factors affecting their decisions here included:
- How distinctive the fibres were – the more brightly coloured, the easier they would be to spot amongst the often many thousands of fibres on each tape
 - How readily the fibres were shed from their source item, as this would influence how likely they were to be transferred to other items, and

⁷¹ INQ014825 (page 10, p 6.6)

- How readily any transferred fibres were likely to be retained by the recipient item – smoother/shinier surfaces were less likely to retain fibres than rough, coarse-textured ones.

9.13 In this way, the scientist could focus their attention on those reference sample fibres to target in their searches of tapes containing recovered fibres.

Identifying Fibres of Potential Interest and Comparing them with Possible Sources

9.14 Initial searching for fibres of potential interest would have involved the use of Low Power Microscopy (LPM).

Low Power Microscopy (LPM)

- 9.15 The LPM - involving magnifications of up to around 40 times normal size, was used to scan tapings, targeting any fibres which appeared similar in colour, shape and dimensions to reference samples of the constituents of other items in the case which could represent potential sources for them. The positions of these target fibres were marked on the upper tape surface, or its backing. As fabrics are often constructed of a blend of different fibre types and colours, it was not unusual for many target-like fibres to be observed on several different tapes and to be marked up for further testing⁷².
- 9.16 Still using the LPM, the fibres were removed one at a time by cutting a three-sided window in the tape around the fibre using a scalpel. Each fibre would then have been picked off and mounted on a microscope slide in a special type of glue or mountant. Every fibre recovered in this way was uniquely numbered, and this number recorded on the microscope slide together with details of the case and item from which it came. Once mounted, each fibre could then be presented for more detailed comparison with the relevant reference samples.
- 9.17 Any fibres that continued to match those in the reference sample when subjected to this greater scrutiny passed on for further testing; any that appeared different were discarded. Thus, each test acted like an elimination round, leaving only those fibres that still appeared to match to go on to the next stage of testing.

⁷² INQ014895 (pages 1-9)

More Detailed Comparison

Polarising Light Microscopy (PLM)

- 9.18 PLM involves inserting a couple of polarising filters into the light path of the microscope at high magnification to enable observation of a property known as birefringence (double refraction) in materials – see also refractive index (RI) of glass. Synthetic fibres are polymers constructed with different refractive indexes, and so this technique enables the forensic scientist to distinguish between acrylic, polyester, and nylon for example. It is also useful in the examination of perceived colour, size and distribution of dye in natural fibres.
- 9.19 Having first applied the technique to identify the types of fibres in the reference fibres, it was then used to triage recovered fibres, enabling some to be discarded as non-matching at an early stage through differences in morphology and/or chemical composition.⁷³

Comparison Microscopy

- 9.20 A comparison microscope is more powerful than an LPM – with magnifications available up to 600 times normal size. It essentially consists of two, high power microscopes linked together by a bridge, allowing two samples of fibres to be viewed side by side at the same time and when physical characteristics such as general appearance and shape, diameter, cross-section, unusual markings, delustrant, and colour can be directly compared between recovered and reference fibres. It uses incident white light, and blue and UV fluorescence.⁷⁴
- 9.21 In the 1990s, some comparison microscopes could accommodate inserted polarisers. While not considered quite as good as a dedicated PLM, it was arguably quicker, and certainly sufficient for initial fibre type identification and preliminary triaging. It was also possible to use a separate Fluorescence Microscope⁷⁵ but, again, this was not a requirement.
- 9.22 Relying on scientists' judgements, microscopy provided a subjective assessment of colour and morphology as to whether fibres from two different sources matched each other. By the early 1990s, however, a more powerful technique had been introduced in the form of microspectrophotometry.

⁷³ INQ014832 (pages 1-11); INQ014905 (pages 1-4); INQ014906 (pages 1-6)

⁷⁴ INQ014829 (pages 1-10); INQ014904 (pages 1-5)

⁷⁵ INQ014901 (pages 1-6)

Microspectrophotometry (MSP)

- 9.23 The microspectrophotometer provided a non-destructive, objective analysis of the colour of textile fibres in the form of a line graph or spectrum. This was based on measurements of the absorption by the fibre of light of different wavelengths – dependent on the colour (dyestuff) used and type of fibre to which this was bonded. When the spectrum from a recovered fibre and a reference sample were shown to match, then the fibre samples were said to be indistinguishable from each other⁷⁶.

Thin-Layer Chromatography (TLC)

- 9.24 The dye of a small proportion of fibres could also be tested further using the older technique of TLC. This required dyestuff to be extracted from individual fibre(s) and then a spot of extracted dye applied to a small, powder-covered plate which was stood upright in an appropriate chemical solution. This solution moved up the plate through the spot of dye extract, separating out its dye components on the way - in much the same way as an ink blot on a sheet of paper can separate into its different components when a drink is spilt on it. Again, if the pattern of coloured spots produced by a reference sample and a recovered fibre matched each other, then they were said to contain the same dyestuff. TLC is a destructive process in that analysis irreversibly alters the fibre and, in some circumstances, can dissolve it altogether. By 1997/98, the technique had been gradually replaced by a more powerful microspectrophotometer but was (and still is) useful for very deeply dyed fibres⁷⁷.

High Performance Liquid Chromatography (HPLC)

- 9.25 An alternative to TLC was the emerging technique of HPLC. This works in essentially the same way as TLC except that the drop of extract is injected into a column of tightly packed powder and separated by liquid solvent being pumped through it under pressure⁷⁸. This technique was never introduced into mainstream casework but was looking like a very promising alternative at the relevant time. The research was led by Dr Griffin at FSANI.
- 9.26 Finally, a technique to identify the chemical composition of synthetic fibres was applied to both reference and recovered fibres. This provided a more detailed

⁷⁶ INQ014840 (pages 1-26)

⁷⁷ INQ014845 (pages 1-17), INQ014910 (pages 1-16), INQ014911 (pages 1-8), INQ014913 (pages 1-6)

⁷⁸ INQ038264 Griffin, R., Speers, S.J., Elliot, L., Todd, N., Sogomo, W., Kee, T.G., *An improved high performance liquid chromatography system for the analysis of basic dyes in forensic caseworks*, *J. Chromatography A.*, 1994, 674, 271-280.

and objective analysis than the PLM, and was therefore a useful confirmatory test of polymer identification:

Fourier Transform Infra-red Microspectroscopy (FTIR)

9.27 FTIR was an instrumental technique in which the infrared region of the electromagnetic spectrum was used to analyse the molecular structure of man-made fibres in order to confirm their detailed chemical composition. In some cases – such as with acrylic and nylon fibres, it could identify sub-classes of the polymer used in their manufacture.⁷⁹ It was a semi-destructive test and, again, the results were produced in the form of a line graph.

Interpretation and reporting of results

9.28 If, after using the highly discriminating microscopy and analytical techniques described, no differences were detected between transferred fibres recovered from one item, and the reference fibres from another item representing a potential source, then the fibres were said to be indistinguishable and potentially to provide evidence of fibre transfer from that source. This would have supported an assertion, for instance, that reference and recipient items had been in physical contact with one another either directly or indirectly. The degree of that support would vary depending on various factors, including:

- how readily, or otherwise, the potential source item shed its constituent fibres and, in blended fibre fabric, the proportion in which each fibre 'type' was shed
- how readily, or otherwise, any potential recipient items would be expected to retain transferred fibres
- the number of transferred fibres found, and whether the transfer of fibres was in one, or both directions between potential source and recipient
- the colour/type and therefore overall rarity of the transferred fibres in the general textile fibre population at large
- the presence of one or more clumps (or pills) of multiple matching fibres

9.29 Other pertinent information from, for example, published scientific literature, fibre manufacturers' production and distribution data, and any relevant fibre databases, might also have been used in evaluating the scientific findings.

⁷⁹ INQ014843 (pages 1-18) : INQ014897 (pages 1-6)

- 9.30 In relation to fibre databases, the FSS had established one in the 1980s based on samples from potential sources of fibres encountered in *1 in every 5 cases submitted to its own, and the Scottish and Northern Ireland laboratories* for fibre examinations. This was useful although it had distinct limitations. Looking further afield, both the Netherlands and Australia had their own databases, but these would obviously not have been as valuable as more local ones in terms of indicating, for instance, what was being worn on local streets at the time.

*These fibre frequency databases – which help with the frequency of occurrence of specific types of fibre and therefore how likely they might be encountered just by chance in the textile fibre population at large, should not be confused with standard reference collections of fibres. These latter help with identifying precise fibre types by providing fibres from authenticated sources for comparison with those arising from casework examinations.*⁸⁰

- 9.31 Forensic Statements and Reports were written in a very similar style in the FSS and FSANI. In the 1990s, these would start with a summary of the reporting scientist's qualifications and experience. They would then list all the items that had been submitted and examined, what their instructions had been in respect of these, and the results of those examinations and conclusions drawn.

OBI-Q5b. How widely used or established was each test or technique, and were there any limitations on its use?

- 9.32 The reliance on textile fibre analysis was not specific to Great Britain and Northern Ireland. By the mid-90's it was considered a mainstream evidence type and was commonly used in forensic laboratories internationally.
- 9.33 Those working in the UK State laboratories of England and Wales (the FSS), Scotland, and Northern Ireland all used the same kinds of tests and techniques for fibre examinations and followed the same generic processes during the period of 1 September 1997 to 15 August 1998. It is not possible on current information to be precise about the specifics of **all** the instrumentation and associated software in use forensically across the UK. This is partly because of the generic format in which the FSANI Laboratory Quality Management Systems were drafted, and partly because of the upgrading of three main instruments around that time (the Comparison Microscope, the MSP and the FTIR). This upgrading reflected the move to Government Agency status for both the FSS – in 1991, and FSANI – in 1996, and the associated investment

⁸⁰ INQ041349 Laing D. et al. *A Fibre Data Collection for Forensic Scientists Collection and Examination Methods*. 1987 J. For. Sci. 32 364-369. (Revised and updated by Adams J. et al 1998)

provided. However, what we can say is that, by 1997/98, both the FSS and FSANI had Leica DMLB comparison microscopes (FSANI's had an additional green light filter on it), and Zeiss MPM400 MSPs – as did the majority of forensic laboratories across Europe; the FSS and FSANI also had new FTIRs.

- 9.34 The FSS had validated methods used on the new instruments and had written Standard Operating Procedures which the scientists followed and were audited against, and FSANI was in a very similar position.
- 9.35 With the arrival of the upgraded instruments came a logistical re-map of the layout of the laboratory which, by 1992 in the FSS, included a **dedicated microscope laboratory** housing a range of microscopes capable of identifying and comparing a wide range of samples. It is believed that FSANI had a similar facility at that time. A separate dedicated **trace analytical laboratory** was also established in each FSS laboratory, containing an FTIR, MSP, TLC, (and other instruments such as a Scanning Electron Microscope for detecting halogen chemicals in anti-flammable clothing/furnishings, for example).
- 9.36 So far as **limitations** were concerned, at the relevant time and following extensive research, the FSS severely cut back on its use of TLC, relying instead on results from the new improved MSPs except on deeply dyed fibres where TLC still added value. The only exception to this was the FSS London laboratory where decisions were still left to the individual lead scientist.⁸¹
- 9.37 It was, and still is, the practice for only a selection of the microscopically matching fibres to be subjected to the further instrumental tests in the trace analytical laboratories. This was simply a pragmatic approach to managing workload and was flexible. For instance, if it turned out that there were two very similar types of recovered fibres – one which matched using MSP for example and one that did not, then many more fibres would have been analysed to confirm this.
- 9.38 Aside from this, strategic choices in individual cases would always have been made in an attempt to choose the most likely analysis to yield the best evidence, and/or improve the timeliness of the work - otherwise each large complex case could theoretically take a lifetime to complete.

⁸¹ INQ041367 Robson R.-*Spectral Variation within Red Cotton Dyes. Proceedings of the 5th European Fibres Group Meeting, Berlin, Germany, 1997: 66-74*

OBI-Q5c. How were these tests and techniques used practically?

9.39 Matching fibres can provide evidence of interactions across a wide range of activities. Common examples in relation to criminal investigations include uncovering evidence of:

- physical contact between a victim and suspected offender, where fibres can also indicate the nature and duration of the contact and, with fibre mapping introduced in the late 1990's, the precise points of contact between them, and confirmation of the weapon used etc.
- a suspected offender's presence at a crime scene when fibres can not only provide evidence of a link but information about the sequence of events there, and what other avenues of investigation might be useful to pursue.
- secondary scenes relating to crime – such as the homes, workplaces and vehicles associated with a suspect, and links between different crime scenes in a series.
- a connection between a suspect and a car seat and, in the cases of multiple suspects, who might have sat where in the car including fibre-plastic infusion where traces of fibres from clothing may be exchanged with the interior thermoplastic surfaces from the car's interior.
- support for one account of events over another to help investigators understand which of more than one suspect is more likely to be telling the truth.

9.40 Fibres have historically provided invaluable evidence in bombing cases, including to link potential offenders with components used in the assembly and handling of explosive devices, and the sites where this occurred.

OBI-Q5d. What sort of forensic material and, how much was required for reliable use of the tests and techniques?

9.41 All of the tests and techniques described above could be applied to single fibres down to less than 5mm in length and 20 microns in width, equivalent to the thickness of a single spider web filament. In relation to analysis of colour and dyestuff, success here would also depend on how deeply dyed a fibre might be.

- 9.42 These days, and at its extreme evidentially, one textile fibre has at least the potential to be critical to an investigation and there are various research and published papers to support this example.⁸² Having said that, a scientist will always try to find more fibres, and more fibres of different types and, if possible, evidence of fibres having been transferred in two directions and not just one, to improve confidence about their potential significance to the case.
- 9.43 The majority of the tests were non-destructive, but where fibres had to be destroyed, the scientist would always try to cut off a section from one end, however small, so they could be independently checked if necessary.

OBI-Q6. Were there any types of test or technique available between 1 September 1997 and 15 August 1998 believed to be unreliable at the time, but have subsequently proved to be reliable?

Linking fibres

- 9.44 On occasion, fibres from an unknown source may be found on two or more items and provide an indirect link between them. These are known as 'linking fibres'. For instance, if a blanket is in contact with a car seat, then fibres could be transferred from blanket to seat. If the blanket is then removed from the car, anyone subsequently sitting on the seat might still pick up fibres from it, but secondarily via the seat. This would provide a link between the blanket and that person but without involving any direct contact between them.
- 9.45 In the late 1990s, there was debate in the scientific community about the value of looking for potential 'linking fibres' between, for example, fibre populations recovered from a crime scene, and those found on the surface of a suspect's or victim's clothing. Some scientists were uncomfortable with the concept, preferring only to report fibre transfers that provided clear evidence of direct contact; but they tended to be amongst the less experienced. In any event, this 'linking fibre' approach was introduced into the FSS in 1996, and it is believed that FSANI also adopted it at around the same time.
- 9.46 In the FSS, linking fibres proved to be particularly useful in so-called 'volume crime' – for instance, where gloves had been worn by prolific burglars, but the gloves themselves had never been recovered. Similarly, prolific car thieves tended to wear the same (fleece) jacket from one theft to another and left fibres from it on different driver's seats. In this way, it was possible to link a series of local crime scenes to clothing seized from a suspect. The approach was accepted in the c

⁸² INQ038265 Grieve, M.C. Biermann, T.W. *The individuality of blue polyester fibres used to provide forensic evidence. Forensic Science International* 2003; 136 (pages 121-122)

- 9.47 courts – particularly with support of published papers describing target fibre studies.⁸³ It was then quickly adapted to major crime scenarios especially in association with 1:1 mapping of fibres which was introduced, again by German scientists, at a similar time.
- 9.48 These days it is a common strategy to look for linking fibres in UK and European laboratories as reflected in the current version (published 01-07-2022) of the European Network of Forensic Science Institutes (ENFSI) Manual of Best Practice, and it has played a key role in some high-profile recent convictions.

OBI-Q7. Were there any types of test or technique available between 1 September 1997 and 15 August 1998 believed to be reliable at the time, but have subsequently proved to be unreliable?

- 9.48 In relation to reliability generally, the mid 1990's (1994-1997) saw the introduction of international accreditation as well as developments in approach and upgrades in instrumentation referred to earlier (see also OBI-Q9b). Accreditation gave comfort that the right instruments had been used, that these had been set up properly, by scientists who had been appropriately trained, and that the methods had been validated - so that the results would be the same whoever and whenever the tests had been performed. Upgrades provided improved design and better-quality optics and lighting for comparison microscopes, better discrimination of colour using an MSP and greatly improved polymer identification using an FTIR. The surge in technology was supported with new approaches and a better understanding of evidential value; all reflected in a raft of new scientific publications on the topic⁸⁴.
- 9.49 At the same time, during the 1990s there was a good deal of collaboration between fibre experts in different forensic laboratories – both in the UK and Europe, in an effort to learn from one another and improve standards. For instance, the FSS, FSANI and the Scottish forensic laboratories set up a UK Fibres Working Group to discuss new technology and methodology, and to take part in internal proficiency tests. Then, in 1992, key fibre experts from the UK, and the German and Swedish forensic laboratories set up a European Fibres Group which, in 1994, became the European Network of Forensic Institutes (ENFSI) Fibres Working Group. FSANI's involvement, which is echoed within their Fibres Bibliography⁸⁵ demonstrated that they

⁸³ INQ038261 Brushweiller, W., Grieve, M.C., *A Study on the Random Distribution of Red Acrylic Target Fibre. Science & Justice*, 1997, 37, 85-89

⁸⁴ INQ041423 *The Forensic Examination of Fibres* 1st & 2nd Eds. 1992; 1999 Robertson & Grieve (rf.2nd Ed. Ch.13 (pages 376-378 list of references)) INQ041425

⁸⁵ INQ014914; INQ014915

keeping abreast of developments in fibre examinations and analysis at the relevant time. The Fibres Working Group was the first to produce a Manual of Best Practice (2001), approved by the ENFSI Board, and members of the same Working Group also collaborated on a revised Edition on the subject published by Taylor & Francis in 1999⁸⁶ and a 3rd Edition in 2018.

- 9.50 It is in the nature of science constantly to keep changing and improving. By itself, this does not mean that anything that went before was not reliable, simply that increased confidence could theoretically be attached, in this case, to fibre matches than hitherto, and therefore that the evidence might be regarded as slightly stronger.
- 9.51 As an example of this, and as mentioned previously, there has been an international decline in the use of Thin Layer Chromatography (TLC) for identifying dyestuffs in fibres since 1996. There was discussion about it at an ENFSI meeting in 1996⁸⁷ when it was generally agreed that the combination of improvements in Comparison Microscopy and upgraded MSP instrumentation and software rendered TLC superfluous except in a small minority of cases, for example, where fibres of interest are very deeply dyed. While there could be issues with the size of sample required, and reproducibility of results between samples, it was not that the TLC technique was classed as wholly unreliable, more that advances in science had simply overtaken it. Not all laboratories stopped using the technique entirely and it is still of some value in certain specific circumstances today.
- 9.52 FSANI was among early pioneers of HPLC⁸⁸ as a further discriminatory test for black acrylic fibres – which featured extensively in gloves and balaclavas worn in their high-profile cases. *FSNI has confirmed that the laboratory was researching HPLC as a means of analysing fibre dyestuffs in acrylic fibres at the relevant time but does not believe it was operational then. They make the point that the Omagh fibres were not recovered until the case was reviewed – from around 2001 onwards, but do not believe HPLC was operational then either.*⁸⁹ It is not that HPLC is considered to be an unreliable technique, more that it has not found favour with the analysts, due mainly to sensitivities of the columns and the implementation of quicker, non-destructive analysis.

⁸⁶ *The Forensic Examination of Fibres 2nd Ed. 1999. Robertson & Grieve.*

⁸⁷ INQ041366 Robson, R., Wiggins, K.G., *Fibre Dye Analysis – A Comparative Study of Analytical Pathways. Proceedings of the 4th European Fibres Group Meeting, London, England, 1996; 32-37*

⁸⁸ INQ038264 Griffin, R., Speers, S.J., Elliot, L., Todd, N., Sogomo, W., Kee, T.G., *An improved high performance liquid chromatography system for the analysis of basic dyes in forensic caseworks, J. Chromatography. A., 1994, 674, 271-280.*

⁸⁹ INQ041292 (pages 1, 2)

Textile Fibres Summary

- 9.53 Textile fibre examinations in the late 1990s were conducted very much as they are today, with just as much emphasis placed on the skill and expertise required to find fibres which potentially matched as on performing the detailed analysis needed to prove this. (Expressing an evaluation of the results has, however, changed considerably in line with other evidence types).
- 9.54 The sensitivity and discrimination of analytical tests were relatively well advanced, enabling very small fibres to be included in comparisons, and giving scientists a good degree of confidence in the matches they reported. At the time, FSANI seems to have had equivalent capabilities as the FSS and both had adopted the 'linking fibres' approach which allowed some weight to be attached to matching fibres from items from two different places even though no potential source had been identified. Now generally accepted as a valid and useful approach, some laboratories were slower to adopt it than others.

10. Forensic Marks and Traces

Professional background of Dr Sarah Jacob

- 10.1 *Sarah Jacob has Bachelor of Science, and Doctor of Physical Chemistry degrees, and over 24 years' experience as a practising forensic chemist. She began her career in the FSS in 2001, and then worked in the same capacity for the independent forensic company, Forensic Access Limited, until 2023 when she became an independent Forensic Consultant.*
- 10.2 *Sarah is recognised as highly skilled in the assessment, strategy setting, laboratory examination and detailed interpretation of cases including complex murder, and other serious high-profile cases, some incorporating joint examinations with experts in other evidence types. She has carried out examinations on behalf of both the prosecution and defence, her involvement extending from crime scene to courtroom.*
- 10.3 *Additionally, Sarah has designed and delivered training courses on marks and trace evidence for CSIs and other police personnel, and foreign law enforcement agencies. She is a guest lecturer at a number of UK universities, with whom she also promotes collaborative research projects. She has recently contributed the chapter on trace evidence for the latest edition of the Royal Society of Chemistry textbook 'Crime Scene to Court: The Essentials of Forensic Science' published 2004.*

*More details of her career CV are included in **Annex A**.*

Introduction to Marks and Traces

- 10.4 **Marks evidence** refers to the comparison of physical characteristics of a wide variety of different sorts of marks, made in different ways on different types of items. Almost any kind of mark can potentially provide an evidential link between crime scenes and victims, and people suspected of having committed the crimes and their homes, work environments and vehicles etc.
- 10.5 Amongst the most common marks encountered in forensic casework are instrument or tool marks, footwear, tyre, and manufacturing marks, and in what are known as 'physical fits'.
- 10.6 Marks left at scenes are typically compared with test marks made from shoes, tools or tyres etc relating to a suspect. Depending on the quality of the scene mark, it can provide conclusive evidence of a link with the suspect. If, however, the mark is fragmentary or of poor quality, then any evidence of a match will be only corroborative. Alternatively, if the scene mark is different from marks

made by an item belonging to a suspect, then it could not have been made by that item.

- 10.7 **Trace evidence** relates to minute amounts of mainly non-biological materials which can be transferred between crime scenes/victims, and suspects, providing evidence of a link between them. Such traces can include almost anything from the physical world such as tiny fragments of glass, flakes of paint, glue, metal swarf particles, and brick dust to name but a few. Of these, glass and paint tend to be the most common. Textile fibres – dealt with earlier is another, specialised kind of forensic trace.
- 10.8 Traces recovered from, say, crime scene and victim items will typically be compared with any samples from potential sources of them (known as reference samples) amongst suspect's items, and *vice versa*. Some traces – for example multilayered paint fragments, are capable of providing conclusive evidence of a link between two items but, more commonly, traces provide corroborative evidence only. Sometimes they are directly associated with marks when they can strengthen the evidence of a link between a mark, and a tool, shoe or tyre which could have made it.
- 10.9 Both trace and marks evidence also have the potential to address the activity which gave rise to the evidence. For example, fresh footwear marks on a windowsill can reflect an entry or exit route to and from a premises, crushed paint on a tool may indicate its use to facilitate forced entry, and loose glass fragments on a garment will allow the scientist to conclude that the wearer of the garment was close to a source of breaking glass.
- 10.10 Particulate traces on clothing often tend to be lost quite quickly from the surface of the items, so it is important for items to be identified, seized and securely packaged as quickly as possible after a crime has been committed.
- 10.11 Reflecting the very small size of traces, the same sorts of stringent steps to avoid contamination are taken within the laboratory as previously described for textile fibres. These are to ensure that any matching traces recovered from an item are related to the incident and could not have been acquired subsequently within the laboratory environment⁹⁰.

⁹⁰ INQ015354 (pages 6-8)

OBI-Q5a. Overview of each test and technique available to the UK State at the relevant time for use in police investigations**Marks - Made by Instruments**

- 10.12 Instrument marks may be left at crime scenes if an instrument or tool has been used, for example, to gain access to a property or its inhabitants. Instrument marks may be impressed marks – such as if a screwdriver has been used to lever open a window frame, or cutting marks – as when a pair of bolt croppers are used to cut through a security chain, or a combination of the two.⁹¹ They can also be left on the body of a victim who has been assaulted with a blunt instrument.
- 10.13 In the late 1990s, instrument mark examinations would have been conducted in a series of stages, starting with a **preliminary visual comparison** between a crime scene mark and the instrument potentially responsible, followed by **recovery and retention of any potential traces** transferred between them. Any necessary **preparations** would have been made – such as cleaning the mark, and making test marks with the tool, for a **more detailed comparison** between crime and test marks. Finally, the results of this would be **evaluated and reported** in a written report or formal statement of evidence.
- 10.14 **Preliminary visual comparison.** An instrument mark would have been submitted to the laboratory either on the item on which it had been made – such as part of a door frame, or as a synthetic rubber cast of the mark. It would then be visually compared with the instrument suspected of having made it in terms of its general appearance and dimensions. Any overall differences here could exclude the mark having been made by the instrument⁹² and stop any further comparison.
- 10.15 **Recovery and retention of trace evidence.** Both instrument mark and tool would have been inspected at this early stage for any traces that could have been transferred between them as these would need to have been recovered before too much handling, and therefore risk of loss, had occurred. Such traces could have included paint from a door or window frame on the instrument and, in the other direction, from the handle of the instrument to the frame, as this could potentially provide additional evidence of a link between them. Any such traces would have been recovered and retained in case required for more detailed examination and comparison.

⁹¹ INQ015408 (page 5)

⁹² INQ015408 (page 11)

- 10.16 **Preparation for Detailed Comparison.** To facilitate more detailed comparison, items bearing instrument marks might have required some prior preparation. For example, metal surfaces might first have needed to be cleaned⁹³, or instrument marks in bone might have required removal of soft tissues⁹⁴. In addition, some marks might have needed enhancement to improve visibility of critical features. This was achieved by casting marks on original items, or recasting synthetic rubber casts.⁹⁵
- 10.17 At the same time, test marks were made with the instrument in a suitable substrate – such as wax or lead, to reflect and preserve any fine details in it, and using the most likely action to best replicate how the original mark had been made. If necessary, the relevant area of the instrument was also cast using an appropriate casting medium.⁹⁶
- 10.18 **Detailed comparison** between the crime mark and test marks was then made using both Low Power Microscopy (LPM) – for better visibility, and Comparison Microscopy for side-by-side comparison.

Low Power Microscopy (LPM)

- 10.19 LPM has already been described in relation to textile fibres; the only difference here being that these microscopes relied on incident/oblique light from above as opposed to transmitted light from below, as this was more appropriate for these sorts of items.

Comparison Microscopy

- 10.20 Comparison microscopy has also been described earlier – again in relation to textile fibres. The main difference here was that the two microscopes involved were slightly differently configured to allow more room for manipulation/precise positioning of marks beneath their lenses and, again, for illumination with incident, as opposed to transmitted light.
- 10.21 If the crime mark had been submitted as a cast, or it was not possible – for example for reasons of its (large) size, to examine the original mark *in situ* on an item under a microscope, then casts of the crime mark and test mark would have been compared.⁹⁷

⁹³ INQ015440 (page 3)

⁹⁴ INQ015408 (page 10)

⁹⁵ INQ015439 (page 4)

⁹⁶ INQ015437 (pages 4-6)

⁹⁷ INQ015408 (page 13)

- 10.22 Features for comparison consisted of damage detail produced through use of the tool, and grinding detail produced on the tool during its original manufacture.⁹⁸ These often appeared as patterns of fine striations and it was the extent to which these striations could be precisely matched up between crime and test marks, that could give a mark comparison its evidential strength.
- 10.23 **Evaluation and reporting.** If sufficient characteristic detail was found in both crime and test marks, it was possible conclusively to link a mark with a specific tool. By the same token, it was alternatively possible to specifically exclude tools if there were significant discrepancies. But sometimes the comparison would only have provided corroborative evidence, the strength of which would depend on the features observed in the mark and whether these had been caused by genuine damage – and were therefore unique, or had resulted from the tool's manufacturing process, when they might not be.⁹⁹

Marks - Made by Footwear

- 10.24 Footwear marks can be recovered from crime scenes for identification or comparison with a pair of shoes relating to a suspect.
- 10.25 Footwear mark examinations followed the same general pattern as instrument marks, namely, **recovery and enhancement, identification, comparison, and evaluation**, although there were some important differences of detail.
- 10.26 **Recovery and enhancement.** Footwear marks at crime scenes were recorded and/or recovered by photographs, adhesive lifts (onto which marks had been transferred), casting, and collection of items on which the marks had been made.
- 10.27 Such marks could be visually enhanced - both at the scene and in the laboratory using a range of physical and chemical techniques depending on the nature of the mark and what it had been made in.^{100 101 102 103 104} These included specialised lighting and photographic techniques, powdering, various lifting techniques – with or without powdering, or applying a chemical reagent, with the results recorded photographically.
- 10.28 **Identification.** The make and model of the footwear which made the mark could potentially be determined by comparing tread pattern features against a

⁹⁸ INQ015408 (pages 13-14)

⁹⁹ INQ015408 (page 9)

¹⁰⁰ INQ015375 (pages 4-8)

¹⁰¹ INQ015434 (pages 4-22)

¹⁰² INQ015405 (pages 3-6)

¹⁰³ INQ015404 (pages 5-14)

¹⁰⁴ INQ015406 (pages 3-6)

collection of footwear patterns held by forensic laboratories – both centrally (in the FSS) and more locally ^{105, 106, 107}.

- 10.29 **Comparison.** To facilitate comparisons between a 2-dimensional crime mark and a specific shoe, a 2-dimensional test mark was made of the tread pattern of the shoe by dusting its sole with black powder, pressing it onto a sheet of clear thin adhesive plastic film, and then protecting this with a sheet of clear acetate. Alternatively, a 'dynamic' mark could be made by the scientist wearing the shoe to make the mark. Test marks were overlaid directly over crime marks to facilitate the comparison^{108, 109}.
- 10.30 Three-dimensional test marks could be made in dry or wet fine sand, plasticine or talcum powder with the resultant marks photographed if necessary. Direct comparison between a crime scene mark cast and test marks, or between the shoe itself and the cast of a crime mark, could then be made.¹¹⁰
- 10.31 The basic features for all comparisons were pattern, pattern dimensions and the presence or absence of wear and damage. Points of similarity or difference between the shoe and the footwear mark were recorded. The manufacturing process produced features which were also taken into account.^{111, 112 113}.
- 10.32 **Evaluation and reporting.** Evaluation of a footwear mark would have relied on an assessment of these features. If sufficient characteristic detail was reproduced, it was possible conclusively to link a mark to a specific item of footwear. It was also possible specifically to exclude footwear if there were significant discrepancies between crime and test marks. For positive comparisons which did not provide a conclusive link, the relative commonness or rarity of the sole pattern of the footwear was taken into account, based on how often the laboratory had seen it before in submissions to them, and the scientist's own experience of the commonness of the pattern.

Marks – Made by Tyres

- 10.33 In 1998, tyre mark examinations involved the same sorts of methods as described above for footwear. Again, the choice of method would be

¹⁰⁵ INQ015377 (page 7)

¹⁰⁶ INQ015385 (page 6)

¹⁰⁷ INQ015381 (pages 7-8)

¹⁰⁸ INQ015387 (pages 4-6)

¹⁰⁹ INQ015386 (page 7)

¹¹⁰ INQ015387 (page 6)

¹¹¹ INQ015378 (Pages 6-8)

¹¹² INQ015386 (page 7)

¹¹³ INQ015383 (page 10)

dependent on the nature of the tyre mark and what material it had been made in.

- 10.34 Similarly, **identification** of a tyre mark could potentially be made on the basis of pattern features visible in the mark when compared against a published list of tyre mark patterns kept at the laboratory.
- 10.35 To facilitate **comparison** between a tyre and a tyre mark, dynamic test marks were made with the tyre still on the vehicle - to reflect the weight of the vehicle and anything else affecting the mark the tyre produced. The tread of the tyre would have been coated in ink and the vehicle pushed over a length of cardboard or paper to record the mark.
- 10.36 The basic features for comparison were the overall size of the tyre, the size and shape of the pattern components and the presence or absence of wear and damage. Points of similarity or difference between the tyre and the tyre mark were recorded. Any features produced during manufacture of the tyre, and which could be reflected in the marks it made, were also compared.
- 10.37 **Evidential strength** was based on an assessment of the features in the mark and the relative commonness of the tyre pattern. In many cases, there was little by way of specific wear or damage features and the evidence would be corroborative and based on the likelihood of finding a vehicle fitted by chance with a tyre corresponding in pattern. For a vehicle fitted with tyres of several different pattern types, the finding of multiple tyre patterns at a crime scene corresponding to those present on the vehicle would significantly increase the evidential strength of a link with it.
- 10.38 By the same token, it was alternatively possible specifically to exclude tyres if there were significant discrepancies between crime mark and test mark with respect to these parameters.

Marks - Made during Manufacturing

- 10.39 Manufacturing marks are those marks produced on items as a result of aspects of the manufacturing process that created them. They can be found on a wide range of products - including plastic bags, adhesive tapes, wire and cable sheathing, and copper piping amongst many others.¹¹⁴ These marks are capable of providing links between items seized by the police at different times and in different places and, on occasion, they can indicate where in a production run one item was likely to have been in relation to another.

¹¹⁴ INQ015410 (page 3)

- 10.40 **Initial examination and comparison** between manufactured items focused on basic characteristics such as colour, size, design, construction, and finish. If two items appeared to match, then a more detailed examination of manufacturing features was carried out.
- 10.41 Features considered for **more detailed examination and comparison** would have included, for example, printed, embossed or moulded markings, impressions, and extrusion detail such as stress marks and scratches.¹¹⁵ Visualisation of such detail was sometimes required and when photography, casting or specialised lighting – including polarised light, was used.
- 10.42 Manufacturing details were then compared - using a microscope if required, noting similarities and differences between the items.¹¹⁶ Some items, notably plastic bags, were compared using a combination of manufacturing marks, and physical fit features (see below) including comparison of torn and cut edges, perforations and seals.
- 10.43 **Evaluation and reporting** of manufacturing mark evidence involved assessing features in the mark and where in the manufacturing process the detail might have been acquired, and whether this detail was likely to be short-lived, or would be expected on all items produced by a particular process. The scientist would then give an opinion as to whether the items were made on the same machinery, consecutively or within a short time of one another, whether there was any connection between the items, or whether there was no connection between them¹¹⁷, and all this would have been presented either in a report or statement of evidence depending on the circumstances.

Physical Fits Evidence

- 10.44 Physical fit examination usually refers to the comparison of the edges of two or more broken, cut or torn materials, to see if they can be precisely physically fitted together - in which case it could be concluded that they once formed parts of one and the same item.¹¹⁸ Common examples of such materials would include pieces of glass, tape, plastic, paint, wood, paper, and clothing.
- 10.45 Initial examinations focused on confirming that their basic characteristics of colour, dimensions, and construction were indistinguishable. The items were then compared systematically in a jigsaw-like fashion to see whether or not they physically fitted together.¹¹⁹

¹¹⁵ INQ015410 (page 9)

¹¹⁶ INQ015410 (pages 8-10)

¹¹⁷ INQ015410 (page 11)

¹¹⁸ INQ015409 (page 6)

¹¹⁹ INQ015409 (pages 8-10)

- 10.46 Physical fit comparisons of delicate items such as adhesive tape or cling film – as in drugs wraps, were challenging as the edges of these items were easily distorted and damaged and required particularly careful handling^{120, 121}.
- 10.47 Once reassembled, some physical fits could provide information about what had happened to the items concerned or what they had come from. For example, reassembly of a window pane from pieces of broken glass could include fracture patterns which might suggest the direction of impact with whatever broke it, and whether it was broken from the inside or outside.¹²² Similarly, physical fit comparisons involving broken vehicle head lamps or indicator lenses could enable the make and model of the car from which they had come to be identified.¹²³
- 10.48 Other types of examination relating to physical fits included comparison of contact, wear and corrosion marks between two surfaces to show that they had been in contact. Such comparisons employed 1:1 photography to facilitate comparison. Comparison of photographic negatives with a camera, or with a printer or enlarger, could be undertaken when features produced as a result of imperfections in the camera frame or negative carrier could be compared.¹²⁴
- 10.49 Using physical fit comparisons, it was possible to obtain a conclusive link if the items concerned fitted together precisely along a sufficiently characteristic join. It was also possible to obtain a conclusive exclusion where they did not, and where there was no obvious possible explanation as to why this should be the case – such as subsequent damage to the edge, or if some parts of this were missing.

Traces – of Glass

- 10.50 When someone was suspected of being in the vicinity of breaking glass at a crime scene, their clothing would be examined for loose glass fragments, or the surface of an instrument or object potentially responsible, for embedded glass¹²⁵. This is because, when glass is broken, tiny fragments scatter in all directions including backwards towards the breaker, and/or can be driven into the instrument or object that broke it.
- 10.51 These tiny loose fragments would then drop off the clothing if it continued to be worn. It was therefore important for scientists to know when this was seized

¹²⁰ INQ015414 (page 7-8)

¹²¹ INQ015442 (page 4)

¹²² INQ015374 (pages 4-8)

¹²³ INQ015409 (page 10)

¹²⁴ INQ015409 (pages 11-13)

¹²⁵ INQ015356 (page 5)

and safely sealed inside its protective packaging as this could be important when it came to interpreting the strength of evidence of any matching glass fragments found. So too could any risks of contamination to which items in the same case had been exposed prior to receipt at the laboratory.

- 10.52 As with virtually all types of forensic evidence, the examination and comparison of items for transferred glass was conducted in a series of stages. These began with the **recovery** of broken glass fragments followed by their **detailed examination and comparison** - using both physical and chemical techniques, and then **evaluation and reporting** of the results in the context of the case.
- 10.53 **Recovering transferred glass particles.** In the late 1990s, glass fragments would either be recovered by shaking or brushing debris from the outer surfaces of the clothing onto a bench covered with clean brown paper, or by shaking the clothing over a shiny metal, purpose-built cone when the fragments would drop into a receptacle placed beneath. Debris collected in these ways was then transferred – usually into a small container¹²⁶, where it was searched under a low power microscope. The number of glass fragments in the debris having a freshly broken appearance was recorded and representative fragments selected for further examination¹²⁷.
- 10.54 At the same time, any instrument suspected of involvement in breaking the glass would be examined under a low power microscope when, again, any freshly broken fragments would be dug out of it and transferred to a container for safe keeping.
- 10.55 A randomly selected sample of these recovered fragments would then be compared with a control or reference sample of broken glass from the crime scene, taking steps to ensure that no contamination of glass fragments from the control item to items relating to a suspect was possible.¹²⁸
- 10.56 **Detailed examination and comparison.** The comparison would have started with measurement of their respective refractive indices using the Glass Refractive Index Measuring system (GRIM).¹²⁹

Refractive Index (RI) using the GRIM

- 10.57 Refractive Index (RI) is a numerical measure of the extent to which a material – in this case glass, can refract or ‘bend’ light. The phenomenon is well known

¹²⁶ INQ015354 (page 7)

¹²⁷ INQ015356 (pages 4-5)

¹²⁸ INQ015358 (pages 5-6)

¹²⁹ INQ015365 (pages 3-14)

domestically – for instance with a pencil which is stood upright in water and when the lower part of the pencil – in the water, appears slightly displaced with respect to the upper part of it – in air, owing to the greater RI of water compared to air.

- 10.58 Glass samples from different sources can potentially be distinguished from one another by virtue of their RI. If some or all of the recovered fragments match those in the control sample, then a comparison of chemical composition would have been undertaken using a Scanning Electron Microscope (SEM).¹³⁰

Scanning Electron Microscope (SEM)

- 10.59 This type of microscope uses a beam of electrons – as opposed to light, as its source of illumination. This provides much higher resolution to pick out considerably smaller detail and it is this, combined with an ability to perform targeted chemical analysis, which enables different glasses to be distinguished from one another, or links between them to be sustained.
- 10.60 Where one or more recovered fragments still matched the reference or control sample of glass, then they were said to be indistinguishable from it and therefore could have come from the same source.
- 10.61 In addition, if one or more of the recovered glass fragments contained part of the original surface of the item from which it had originated, then Interference Microscopy and examination under UV light could have been used to provide information about what sort of item that had been.

Interference Microscopy and examination using UV light

- 10.62 In Interference Microscopy, light is manipulated to show up fine detail in a sample. This could distinguish, for example, whether or not recovered fragments had originated from a flat source of glass – such as a window pane, or a non-flat or curved one such as a container of some kind, and how recovered fragments compared with the control sample in this respect.¹³¹
- 10.63 If flat, then examination using UV light might reveal fluorescence associated with the presence of tin on one of its surfaces, indicating manufacture by a specific process used for window panes.¹³²
- 10.64 In addition, where appropriate, fragments from recovered and control glass samples were tested and compared using a heat treatment process, with their

¹³⁰ INQ015373 (pages 5-16)

¹³¹ INQ015361 (pages 10-11)

¹³² INQ015361 (pages 9-10)

RI measured both before and after. If the RI of a fragment changed, then this indicated that the glass originated from a source of toughened glass¹³³ – such as a car window.

- 10.65 Evaluations of glass evidence did not provide conclusive links because glass items tend to be mass-produced and it is therefore not possible to link any glass fragments to a specific source. Glass evidence can, however, provide good corroborative evidence.
- 10.66 **Evaluation and reporting.** At the relevant time, and having established that recovered glass fragments matched the control sample in all the tests described above, the strength of the evidence was assessed on the basis of the circumstances of the case including the prosecution and defence version of events. Factors taken into account here would have included: the likelihood of transfer of glass to the item; the likelihood of persistence of glass on the item including any time delay before it was seized; the number of corresponding fragments; the number of other glass sources present; and the frequency of occurrence of the control glass as assessed against information about control glass samples previously examined at the laboratory.¹³⁴
- 10.67 In essence, the significance of the findings was dependent on the likelihood of finding the amount and type of corresponding glass fragments on a suspect item by chance if they did not relate to the incident in question.

Traces – of Paint

- 10.68 When a dry painted surface is damaged in some way, the paint may fragment and flakes of it be transferred to other items with which they come into contact. Looking for evidence of paint transfer in criminal investigations involves the same general stages as glass transfer although some of the methods of analysis are rather different.
- 10.69 **Recovery of paint fragments.** In the late 1990s, loose dry fragments of paint were recovered in much the same way as for glass - by shaking or brushing debris off the outer surfaces of a garment onto a bench lined with brown paper, or into a cone, and transferring the debris into a small container for further examination.
- 10.70 Samples of paint which had been applied wet and then dried, or impacted, or smeared paint were also sometimes recovered from items during examinations at the laboratory.¹³⁵ In these circumstances, paint fragments

¹³³ INQ015366 (pages 7-8)

¹³⁴ INQ015429 (pages 3-7)

¹³⁵ INQ015416 (pages 3-9)

would have been removed from an item using a scalpel or tweezers as appropriate. Wet paint would have been sampled using a swab.

- 10.71 **Examination and comparison.** Examinations would start with a search among the recovered debris for paint flakes with the aid of Low Power Microscopy as described earlier. The number of paint fragments and their condition was recorded and representative fragments selected for further examination.¹³⁶
- 10.72 A control or reference paint sample recovered from the crime scene was examined visually – again including using Low Power Microscopy, and as with glass samples, taking steps to ensure that no contamination of paint from the control item to items relating to a suspect was possible.¹³⁷

Low Power Microscopy and Comparison Microscopy

- 10.73 The selected recovered fragments of paint relating to a suspect item were initially compared with representative fragments of the control sample of paint using a low power stereomicroscope.^{138 139} Any paint fragments believed to correspond were then compared with the control sample using a comparison microscope utilising white light and fluorescent light.¹⁴⁰
- 10.74 Consideration was given to the number of layers of paint present; the colour and texture of the layers; the size, shape, colour and density of any constituent particles within each of the layers including metallic particles; and any fluorescence effects. Similarities and differences between the recovered and control paint samples were noted.¹⁴¹
- 10.75 The examination was terminated at this stage if recovered and control paint samples were found to be different. It was also terminated if there was a sufficient correspondence in multi-layered paint samples for this to provide particularly strong associative evidence in its own right.
- 10.76 In other circumstances, for example involving single layer paint samples, if recovered and control paint samples were found to correspond microscopically, then further tests were applied to them.¹⁴² These included

¹³⁶ INQ015419 (pages 4-5)

¹³⁷ INQ015421 (pages 4-8)

¹³⁸ INQ015416 (page 10)

¹³⁹ INQ015444 (page 3)

¹⁴⁰ INQ015416 (page 10)

¹⁴¹ INQ015445 (pages 2-8)

¹⁴² INQ015416 (page 11)

FTIR, SEM and Pyrolysis Gas Chromatography-Mass Spectrometry.^{143 144 145 146}

Fourier Transform Infrared Spectroscopy (FTIR)

- 10.77 As described earlier in relation to textile fibres, FTIR was an instrumental technique used to identify the detailed chemical composition of, in this case, tiny paint samples, using the infrared region of the electromagnetic spectrum to reveal their molecular structure.

Pyrolysis Gas Chromatography-Mass Spectrometry

- 10.78 Again, as we have already seen in relation to explosive substances, gas chromatography was used to separate out different components in a sample through the chemical and physical interactions of the sample as it is pushed by gas through a long thin tube filled with powder. Adding a mass spectrometer onto the end of this - deploying electric and magnetic fields in a strong vacuum, enables the components to fragment and separate further as a means of identifying them. Pyrolysis refers to the initial heating of the paint sample in a furnace to convert it into smaller components for analysis via Gas Chromatography.
- 10.79 **Evaluation and reporting.** At the relevant time, paint evidence had the potential to provide a conclusive link if the paint under consideration was sufficiently characteristic - that is the sample was composed of multiple layers of paint and the paint layers were sufficiently distinctive and therefore discriminating in terms of colour and/or composition. Other paint samples had the potential to provide only corroborative evidence.
- 10.80 As to the strength of this evidence, in Great Britain, assessments would have taken into account the likelihood of finding that type of paint by chance based on the amount, location and appearance of the recovered sample (for example, was it crushed?) and also its commonality. The background information used to interpret cases would have been based on the forensic scientist's own experience from previous cases.

¹⁴³ INQ015416 (pages 11-14)

¹⁴⁴ INQ015423 (pages 3-12)

¹⁴⁵ INQ015425 (pages 3-9)

¹⁴⁶ INQ015427 (pages 3-9)

Other Types of Trace Evidence

- 10.81 Many other types of material could become trace evidence in a case depending on specific case circumstances. Examples include glue, brick dust, nail varnish, make-up, condom lubricants, waxes, and polishes.¹⁴⁷ The method of recovery of such traces and their subsequent examination was decided on a case-by-case basis and dependent on the type of material in question. In some instances, it would have been necessary to obtain reference materials to assist with the analysis and interpretation of results.¹⁴⁸
- 10.82 Sometimes, the nature of a similar trace on recovered and suspect-related items might be unknown and when analytical instrument libraries – in the FTIR, would have been consulted in attempts to identify it.¹⁴⁹ Microscopy and other analytical instruments – such as SEM and Gas Chromatography-Mass Spectrometry could also be deployed.
- 10.83 Tests which were performed infrequently were verified by the use of suitable quality control methods such as the analysis of standard materials to ensure that the analyst and test were producing reliable results.¹⁵⁰
- 10.84 Assessments of the significance of the findings would have started with whether the material on both recovered and suspect or reference item matched. The evidential strength would then have taken into account the likelihood of finding that type of material by chance based on the amount, location and appearance of it, and its likely commonality. Commonality would have been assessed based on the scientist's experience and reference data gathered as part of the examination.

OBI-Q5b. How widely used or established was each test or technique, and were there any limitations on its use?

- 10.85 All of the different kinds of marks *and traces* evidence described above were in widespread use across the UK at the material time, and the analytical techniques in use in connection with them were well established at the time. *The assessment of FSANI's approach and capabilities is mainly based on their SOPs at the time, with gaps filled in through correlation with the then current practice in the FSS laboratories in England and Wales.* From the documents to which access has been provided, there were some gaps as to the detail of

¹⁴⁷ INQ014846 (page 6)

¹⁴⁸ INQ014846 (page 7)

¹⁴⁹ INQ015471 (pages 5-12)

¹⁵⁰ INQ014772 (page 2)

what was done – for instance there were no quality documents provided by FSANI at the time of writing relating to tyre marks, and some minor differences between laboratories in some of the techniques. In respect of footwear marks, for example in Great Britain, comparisons were always carried out using test marks prepared from reference or suspect footwear, and by direct overlay onto the crime mark, including casts, whereas in FSANI it seems this may not always have been the case. But generally, tests and techniques all ran along roughly similar lines.

In terms of whether this could be indicative of a slightly less rigorous approach in Northern Ireland, there are several points to note. Overall, the methodology for marks and traces evidence appeared to be broadly similar between Northern Ireland and Great Britain. However, slight differences in methodology relating to these types of evidence between laboratories were not uncommon. Indeed, there were minor differences between different laboratories within the FSS in England and Wales around this time. In addition, the full documentation of laboratory processes with a view to gaining formal accreditation, including for the examination of marks and traces evidence, was in its infancy around 1997 and 1998. The gaps in the information referred to above could well be as a result of the evolution of this process.

FSNI have been asked to clarify whether there were any discernible differences in the tests and techniques used by FSANI and that of forensic laboratories in Great Britain. They responded by saying that they cannot offer a comparison of techniques used in other forensic laboratories over the time period.¹⁵¹

Overall, there is nothing to indicate that the approach to marks and traces evidence was less rigorous in Northern Ireland than elsewhere in the UK at the relevant time.

- 10.86 Any improvements made to these techniques since then represent general advancements in technology and approach and will have served only to strengthen evidential significance – through better sensitivity and discrimination for example, rather than to address any fundamental flaws in them. For instance, there have been advances in the casting media used to recover instrument marks from crime scenes and to cast test marks which result in better quality casts for comparison.
- 10.87 So far as **limitations** are concerned, in the late 1990s, forensic science laboratories were dealing with high volumes of cases to the extent that there

¹⁵¹ INQ041292 (pages 2-3)

were backlogs of work in some areas. At the same time, police force budgets were coming under increased pressure. This led to the beginning of a narrowing focus on which items might be tested for what. Analytical techniques in use needed to be more cost-effective and capable of dealing with a high throughput of cases. They also needed to be non-destructive wherever possible to allow for re-testing by the defence if required.

As to how FSANI might have been affected by these sorts of pressures, FSNI has said that they 'have neither current staff nor corporate records which could validate the following statements:

- 'This led to the beginning of a narrowing focus on which items might be tested for what'*
- 'increased pressure on police budgets'*
- 'analytical techniques in use needed to be more cost effective and capable of dealing with a high throughput of cases'.¹⁵²*

However, given that such budget pressures with their associated consequences were coming into play in FSS laboratories in England and Wales at the time, it seems likely that constraints would have been felt in one form or another throughout UK laboratories including in Northern Ireland. Indeed, contractual arrangements, cost recovery, case turnaround times within the laboratory, and quality standards featured heavily in FSANI's Annual Report and Accounts for 1997-1998.¹⁵³

10.88 At the same time, the FSS was starting to feel pressure from its new competitors to the extent that it closed one of its laboratories – at Aldermaston (see OBI-Q8). This meant that some police forces in the South East of England had to travel further to access forensic facilities, which obviously affected the extent to which they could just 'drop in' to discuss changing requirements in a case, or check on progress.

10.89 Technical limitations would always include the quality, or amount of detail present in marks, the fragility, or completeness of edges in physical fits, and the amount of trace material available to be found and therefore available for testing. Some marks evidence was capable of providing conclusive links between crime, and reference or control marks, or definitive exclusions. But much of the work was limited to some level of corroboration, when the strength

¹⁵² INQ041292 (page 3)

¹⁵³ INQ015472 (pages i, ii)

of evidence depended upon the extent of similarity between crime and test marks, and the likely frequency of occurrence of traces.

- 10.90 In addition, the strength of footwear mark evidence may diminish if there is a time delay between an incident having occurred and subsequent recovery of footwear items. This is because the footwear may have been worn during the intervening period with associated changes in the appearance of the sole. Footwear evidence may also be limited if there is a question mark over the ownership of a pair of shoes, or if it is not possible to confirm whether footwear marks left at a crime scene were necessarily made at the time of the incident in question.
- 10.91 The identification of footwear patterns at a scene may have been limited if the pattern under consideration was not held in the reference collection(s) used. These collections comprised local ones compiled from footwear submitted to the laboratory in question in the normal course of casework, and/or compiled by other laboratories. For instance, the FSANI Laboratory used both its own, and the FSS Chorley Laboratory's collections when trying to identify footwear patterns at crime scenes.
- 10.92 The same general principles apply to instrument and tyre marks. Both types may be too poorly defined for reliable comparison, and the strength of the evidence may diminish if there is a time delay between an incident and when a specific tool or vehicle was found. Any usage during this time may have introduced changes in the appearance of the tool or tyre and therefore the marks it leaves when used and, in the case of tyres, these may even have been replaced.
- 10.93 Trace evidence is limited as an evidence type in that the absence of corresponding material on an item may not help address the issues under consideration, leading to an inconclusive result. The interpretation of some trace evidence cases may also be hindered by a lack of background data. For loose material in particular, the possibility of contamination is an important consideration and may be an issue in some circumstances. In addition, loose fragments can be lost quickly from the surface of clothing which gives a more limited time window for a viable examination.

OBI-Q5c. How were these tests and techniques used practically?

- 10.94 Forensic marks and traces represent core types of evidence with applications in a wide variety of investigations – from burglary to murder, drug dealing to terrorism. For instance, marks found at a crime scene could help to indicate – sometimes conclusively, that a suspect was present at the scene, used a specific tool to break into the premises or injure a victim, assembled drugs

wraps or components of a bomb, was involved in a traffic accident and/or caused criminal damage to property, and so on.

- 10.95 Where there was no suspect, marks could provide important information, for instance, about the type of footwear the offender wore, the tyres on the vehicle they drove, the tool(s) they used, and whether they were likely to have been involved in a series of crime scenes and not just the one at hand.
- 10.96 When combined with chemical traces, evidence of a link with a specific person might have been significantly enhanced – for instance where minute paint flakes or glass fragments from a damaged premises were found on a tool, or on their clothing, alongside the finding of a mark made by the tool at the premises. Unusual traces found on a victim might have suggested a specific occupation for the offender.
- 10.97 The position and nature of marks and traces can provide more information about the sequence of events at the crime scene by indicating what the offender might have been doing at the time and confirm their involvement in the crime. For instance, footwear marks on windowsills can indicate how they got in and/or out of a premises, and matching glass fragments in combings from their hair could suggest that they had been actively involved in the break-in. Any or all of this can help an SIO to focus their investigation more effectively than might otherwise be possible.

OBI-Q5d. What sort of forensic material, and how much was required for reliable use of the tests and techniques?

- 10.98 Generally, the more clear and more complete a mark was, the better the evidence of a link with the item that made it, and this is why enhancement techniques have always been so important in marks evidence. It is not possible to say how large a mark needs to be to obtain a result because much will depend on which part of the item making the mark has been captured in it, and whether this contains sufficient good quality features to make a good comparison with the reference mark.
- 10.99 Marks evidence was deemed reliable around 1998 and is still deemed reliable today. While there was inevitably some subjectivity in comparison and interpretation of features, marks comparisons have always been peer reviewed by a second scientist prior to reporting, and this continues to be a requirement.
- 10.100 In terms of traces, by 1998 the techniques available for analysis were relatively sensitive, and results could be expected from a single fragment of glass or a flake of paint measuring only a fraction of a millimetre across.

OBI-Q6. Were there any types of test or technique available between 1 September 1997 and 15 August 1998 believed to be unreliable at the time, but subsequently proved to be reliable?

10.101 In general terms, techniques for examining and comparing both marks and trace evidence have not changed fundamentally between the late 1990s and now. There are some minor differences, for example, in how marks are recovered and/or enhanced, but none of these would automatically convert an unreliable test or technique into a reliable one – it would be more likely simply to affect the strength of evidence that could be attached to a set of findings.

10.102 But what has changed is technology, particularly in relation to analytical tests on traces, in that modern instruments are significantly more sensitive than those in use then – ie. they require less material for the tests to work, and they are more discriminating – and therefore better able to distinguish between similar samples than hitherto. But, again, it is difficult to see how this could result in a test regarded as unreliable at the time, being found now to be reliable.

OBI-Q7. Were there any types of test or technique available between 1 September 1997 and 15 August 1998 believed to be reliable at the time, that have subsequently proved to be unreliable?

10.103 Looked at another way, the better discrimination of modern analytical techniques could theoretically mean that samples thought to match in the late 1990s, might now be shown not to match. But this possibility should have been reflected in a lower strength of evidence than it might be possible to attach to the same findings now.

10.104 In relation to sensitivity, it is not clear to what extent the risks of trace evidence contamination – both prior to submission of items, and within the laboratory, were fully understood and/or acknowledged in the late 1990s as Quality documentation is variable. This matters particularly in relation to re-investigations of old cases, when modern, more sensitive techniques are applied to items and samples that were collected and initially examined many years ago.

Marks and Traces Summary

10.105 Examinations for a variety of marks and trace evidence were in widespread use across the UK in the late 1990s. While there are some gaps in our information, the main forensic laboratories across the territory appear to have approached the work in a similar way, with only relatively minor differences in

10.106 protocols between them. Fundamentally, examination techniques have remained very much the same since then, although there has been an increase in the sensitivity of some of the analytical tests employed in relation to traces. This could potentially be reflected in increased strength of evidence of links identified between items from different places.

11. Questioned Documents

Professional background of Melanie Pugh

- 11.1 *Melanie Pugh holds a Bachelor of Science Honours degree in Analytical Chemistry from the University of Wales, Swansea and, from 1998 until its closure in March 2012, she was employed by the HOFSS, where she was a specialist in the scientific examination of handwriting, signatures, and disputed documents. She now works as an independent forensic practitioner within StocktonPugh, which specialises in the examination of questioned documents. She provides reports and expert witness statements to the police, the Crown Prosecution Service, government departments, and solicitors involved in criminal prosecution and defence casework, and to the Criminal and Civil Courts in the UK and overseas.*
- 11.2 *In addition to casework, she acts as an International ISO 17025 assessor and represents the field of Questioned Document Examination on the Home Office Forensic Regulator's Office Interpretation Group. She is also a member of the Chartered Society of Forensic Sciences, and an associate member of the European Network of Forensic Handwriting Examiners (ENFHEX), and of the Documents Working Group (EDEWG).*

*More details of her CV are included in **Annex A**.*

Introduction to Questioned Documents

- 11.3 Questioned Document examination is the forensic discipline concerned with the analysis of documents whose authenticity, origin, or authorship is in doubt.
- 11.4 It covers the principles and methods used to examine handwriting, signatures, typewriting, printing, paper, inks, and alterations to determine whether a document is genuine or has been tampered with. The field combines scientific techniques with expert visual analysis to compare questioned material with known standards, identifies how a document has been produced, and detects any additions, erasures, or forgeries.
- 11.5 Ultimately, it aims to provide reliable, evidence-based opinions that assist investigators and courts with challenges involving written or printed documents.
- 11.6 Several forensic laboratories in the UK had a questioned documents capability at the relevant time. These included the FSS laboratories at London, Wetherby and Huntingdon, FSANI had a small unit, and there were a number of staff within Scottish identification bureaux who undertook the work part-time. In addition, the private laboratories of the Laboratory of the Government Chemist

(LGC) and Document Evidence Limited (DEL) (see also OBI-Q8a) provided questioned document services

OBI-Q5a. Overview of each test and technique that was available to the UK state between 1 September 1997 and 15 August 1998 for use in police investigations

11.7 The core methods available to UK forensic practitioners and used in police investigations during the relevant period were as follows:

Handwriting and Signature Examinations

11.8 These could help to determine the authorship of handwriting or signatures by comparison of documents whose provenance was questioned with known examples from a suspected author. It could also help to establish whether or not a body of handwriting or signatures could be attributed to the same person.

11.9 The writing was first examined visually, and then microscopically using both a low-power stereo microscope (LPM) and a comparison microscope to identify distinguishing letter forms, slant, pressure, spacing, joins and idiosyncratic features. This remains the foundation of handwriting examination.¹⁵⁴

11.10 When handwriting appears on hard, non-porous surfaces (like plastic), forensic document examiners *can* still undertake a handwriting comparison with a suspect's reference samples, often using the same traditional comparison methods as on paper (analysis of letter shapes, proportions, spacing etc) but the interpretations may differ.

11.11 The main challenges are that:

- Characters may be constructed differently to allow for easier shape formation, eg. an 'O' constructed as two joined curves
- The ink used may sit on the surface of the plastic rather than be absorbed into the paper fibres. This may lead to smearing or smudging of ink, and hinder the determination of letter shapes.

11.12 The main difference is that samples should be taken from suspects using the 'like with like' rule of thumb for forensic science examinations, so samples should be created on a similar substrate and using a similar writing implement.

¹⁵⁴ INQ041351 *Osborn, A. S. (1910). Questioned Documents: A Study of Questioned Documents, Chap IV onwards*

- 11.13 Any matching features are interpreted with caution, because the surface effect may have introduced artificial features within a person's natural handwriting style.

Indented Impression Detection and Recovery

ESDA (Electrostatic Detection Apparatus)

- 11.14 **ESDA** was a widely used, non-destructive method (already standard in document laboratories by the 1990s)¹⁵⁵ to reveal **indented writing** – ie. the indented impressions that writing tends to leave on consecutive underlying sheets in a pad or stack of paper. Indentations can reveal the content of writing on missing top sheet(s) including potentially important detail such as names, phone numbers, planning notes etc. In this way, it can link planning activity to individuals and groups of individuals. ESDA involves placing the questioned document, covered with a piece of cling film, onto a brass bed and flattening it using a vacuum. The surface of the paper is then charged with a high voltage electric wand, and fine black powder, or toner, sprinkled over it. This toner is attracted to areas where fibres in the paper have been disturbed eg. indented by writing, making them stand out compared to the rest of the paper surface. The image of the indented writing is then captured either by lifting it using sticky-back plastic, or by photography. Marks caused by printers are also recoverable as are fingerprints.

Light-based Imaging

Ultraviolet (UV), Infrared (IR), Photographic and Video-spectral Comparators (VSC)

- 11.15 Inspection of documents using different light sources such as ultraviolet, infrared, and photographic and VSC, enabled examiners to reveal obliterated/erased text and to differentiate inks that look the same to the eye. In this technique, a sheet of paper is placed in a small cabinet containing a variety of light sources, filters and with a camera above. Under UV, light paper will be seen to luminesce to different degrees depending on the amount of optical brightener it contains. All genuine ID documents and currencies around the world are manufactured using controlled paper types which do not contain optical brighteners. Genuine documents therefore appear dull under UV light whereas counterfeits luminesce.
- 11.16 Under normal or high intensity light, inks can either absorb the light and appear dark, reflect the light and disappear, or luminesce and appear bright. Different

¹⁵⁵ Foster + Freeman

inks can react in different ways, and their response picked up using filters and a camera which can record the reaction in the visible and infra-red regions of the spectrum. The VSC was an established tool by the 1990s in major labs. The methods are non-destructive and essential for ink differentiation, paper comparison and detection of alterations.¹⁵⁶

Ink Analysis

Thin-Layer Chromatography (TLC)

- 11.17 TLC was the standard technique for comparing soluble/dye-based inks (ballpoint/rollerball/marker inks) in the 1990s. Tiny samples were extracted and separated on TLC plates - very much as described for textile fibres earlier, to compare ink composition between questioned marks and pens suspected of having made them.

Paper and Physical Material Analysis

- 11.18 Paper characteristics - such as composition (including fibre analysis), weight, finish, watermarks and manufacturing marks, and physical matching could link a questioned document to other documents or to a particular source of paper. This routinely relied on transmitted-light – when light is shone through the paper from below, and low, and high- power microscopic examination as required.
- 11.19 In cases involving **physical fits** (see also Marks and Traces), torn or cut documents are reconstructed by precisely matching edges, fibre patterns, and surface features to show whether two or more fragments once formed parts of the same single sheet. For instance, in relation to anonymous letters, characters or images cut from newspapers and magazines could be physically linked to the source document (if available) using microscopic analysis of the paper fibres and cut edges.

Typewriter Comparisons

- 11.20 Typewritten documents were more common in the late 1990s than they are today. A forensic document examiner undertakes several key examinations when dealing with typewritten documents, aiming to identify the machine used, detect alterations and assess authenticity. These examinations typically included:

¹⁵⁶ Ellen, D., Day, S., & Davies, C. (2018). *Scientific Examination of Documents: Methods and Techniques, Fourth Edition (4th ed.)*. CRC Press. <https://doi.org/10.4324/9780429491917>, (pages 130-141)

- **Typeface and alignment examination** which involved the analysis of the shape, size, and design of characters, as well as their vertical and horizontal alignment, line spacing, and uniformity. This helped to determine the make and model of the typewriter, and whether two documents could have been produced on the same machine. The examiner evaluated similarities and differences to reach an expert opinion on common origin or exclusion.
- **Mechanical defects and wear** analysis because individual machines often develop faults - such as chipped typefaces, bent typebars, uneven striking force, or misaligned letters. These features could uniquely identify a specific typewriter if they appeared consistently in both the questioned document and known samples from the machine.
- **Ribbon and ink analysis.** Here the type of ribbon (fabric, carbon, or film), its condition, and the density of ink transfer were all assessed. Traces on the ribbon itself may reveal the text typed, allowing reconstruction of content or confirmation of use. In some laboratories, the contents of the carbon ribbon could be 'read' using the Ribbon Analysis Workstation (RAW) and the contents inspected for the questioned text.
- **Correction and alteration detection** because the use of correction fluids, correction tape, or overtyping can indicate document manipulation. Document examiners used oblique lighting to detect erased or substituted text and to determine the sequence of entries. Correction tape itself could be examined to reveal the contents of the erasure.

Photocopier/printer and Toner/ink-jet Identification

- 11.21 For non-impact (copier/printer) printing, class characteristics and microscopic features were examined. Toner and printing mechanisms analysis could sometimes tie a set of documents to a common source or specific device if it was available. If the document was produced using a colour printer or colour photocopier, the model of machine (and often from this, its location) could be traced by the analysis of a yellow dot pattern on the documents, the so called "bit map" or Machine Identification Code (MIC). Such a code was introduced and printed on to documents by the manufacturers.
- 11.22 In the examination of photocopies, forensic document examiners considered whether a copy was genuine, altered, or derived from a particular machine. They studied features such as toner distribution, paper texture, magnification effects, and any visible copying artifacts. Particular attention was given

to trash marks. These are small, recurring defects caused by dirt, dust, scratches, or damage on the copier's glass, drum, or internal components. These marks often appear in the same position on multiple copies made from the same machine, allowing examiners to link a questioned document to a specific photocopier. By comparing trash mark patterns, an examiner seeks to establish the source of a photocopy, detect whether parts of a document were substituted or reassembled, and evaluate whether it had been deliberately manipulated or fabricated.

- 11.23 Laser printers, ink jet printers and other devices linked to computers were being used in offices to print documents in the early 1990's, and by the mid/late 1990s such forensic printing comparisons were routine in larger labs. It soon became apparent that these newer desktop printing machines lacked the distinguishing features present within traditional printing processes and documents produced using typewriters, and therefore it became more difficult to discriminate between documents produced by them. In addition, when the ink ran out in these machines, the cartridges which housed any defects were replaced.

Letraset/stencilling

- 11.24 When examining documents produced using dry transfer lettering (such as Letraset) or stencilling, the focus was on identifying how the lettering was applied, whether it was consistent throughout the document, and if any parts had been altered or added later.
- 11.25 With dry transfer lettering, examiners looked for signs that individual characters were manually rubbed onto the paper - such as slight variations in alignment, pressure marks, or partial transfers where parts of a letter are missing or overlaid. Differences in spacing, line orientation, or character size may indicate that separate letters were applied individually rather than typed or printed as a continuous line. Under magnification or oblique lighting, examiners may detect indentation patterns, transfer film residue, or areas of surface disturbance on the paper. Comparison with known Letraset sheets or similar products could help identify the typeface and manufacturer, which could be useful for dating the document or confirming its authenticity.
- 11.26 In the case of stencilled documents, examiners assess the type of stencil used, and the pen used to apply the characters. With both methods, examiners aimed to determine whether the lettering was applied contemporaneously with the rest of the document, and whether there were any identifying features or marks which would be of help in identifying the source.

Malicious Communications

- 11.27 Before the advent of digital databases, Forensic Document Examiners maintained what was known as a Malicious Communications (Malcoms) Database. This was a collection of threatening, abusive, or anonymous written communications which had been sent to individuals or organisations - especially involving public figures, politicians, government departments and companies involved in research of a controversial nature. It was used for comparison and intelligence purposes with the main purpose of identifying patterns or repeat offending, and to support case linkages across different jurisdictions and/or police forces.
- 11.28 This early, pre-digital database originally consisted of photocopies or photographic reproductions of letters, notes, or other communications. These were stored manually in ring binders or filing cabinets, often categorised by:
- Type of communication (Animal Rights, Political/Racial threats etc.)
 - Writing style (handwritten, typed, printed)
 - Linguistic features (common phrases, tone, themes)
 - Geographic origin or police division
- 11.29 Forensic Document Examiners and investigators would visually compare new exhibits against these reference binders to identify similar handwriting, layout, phrasing, or document features. Notes and annotations were added by examiners to record any linkages between cases.

Stamp Marks

- 11.30 The examination of stamp marks and stamp impressions involves analysing impressions made by rubber, metal, or inked stamps to determine their authenticity, origin, and method of application. Forensic document examiners study the design, alignment, size, and spacing of the lettering or emblem, as well as ink type, pressure, and distribution. They look for signs of wear, damage, or distortion that may uniquely identify a particular stamp or indicate repeated use over time. By comparing questioned impressions with known examples or using original stamping devices, the examiner can assess whether a stamp mark is genuine, duplicated, or altered, providing important evidence about the document's authenticity and sequence of production.

Traditional Printing Methods

- 11.31 Traditional printing methods are fundamental to understanding the origins and authenticity of printed documents in forensic work. A forensic document examiner uses stereo zoom microscopy and specialised lighting to identify the print processes — **letterpress**, **intaglio** (engraving), **lithography** (fixing the image on a metal plate and making it ink-receptive), **gravure** (form of intaglio), **and offset printing** within a document - and would use these characteristics to distinguish original documents from copies, detect signs of forgery or alteration, or to link documents together to a common source.

Recovery of Obliterated or Chemically Treated Text

- 11.32 Chemical reagents (used sparingly to avoid damage) and optical methods (using different wavelengths of light and filters) were used to recover erased/obliterated writing. Non-destructive optical methods were preferred as the first option.

Damaged Documents

- 11.33 The examination of damaged documents focused on assessing the nature and extent of the damage — whether from water, heat (char), light, stains, tears etc. The first step was to stabilise and preserve what remains so that further examination will not cause additional loss.
- 11.34 Then specialised lighting (oblique, and transmitted light), digital imaging, and possibly specialised light sources, was used to recover faint or degraded text, impressions, or features (e.g. indented writing). Fading effects caused by light or chemical action are evaluated, and any distortion (paper warping, swelling, shrinkage) documented.
- 11.35 When dealing with water-damaged documents, forensic examiners have to carefully dry and stabilise the material before assessing ink diffusion and paper distortion.
- 11.36 For charred documents, special lighting techniques such as infra-red or transmitted light are used to enhance faint writing or impressions, and fragile material is stabilised to prevent further loss.
- 11.37 Across all types of damage, the examiner's goal is to preserve evidence, recover legible text, and determine whether the damage occurred naturally, accidentally, or deliberately to conceal or alter information.

Postal and Postal-mark Analysis (Postmarks)

- 11.38 Postmarks were examined to establish where a letter or package was posted or routed and when documentary timing and locations could be critical in linking planning or communications to geographic areas. The pattern of blue phosphor dots on an envelope would help identify its origin so, if re-used, it could be traced back to a possible original sender. Co-operation with Royal Mail/Postal Services was standard investigative practice.

OBI-Q5b. How widely used or established was each test or technique, and were there any limitations on its use?

Overall, based on the material available (including SOPs, case documentation and associated records), FSANI appears to have provided a broadly comparable range of forensic services to those available elsewhere in the UK at the time, applying similar tests, techniques and laboratory processes, although the position is less clear in relation to the extent of its access to, and use of databases and other shared resources.

- 11.39 The **most widely used and established** of the tests and techniques described above were those capable of:
- **Linking documents to individuals**, including handwriting comparison between questioned documents and known examples of handwriting from suspect individuals. Any fingerprints and/or DNA from the same document could significantly improve the strength of a link between a person and a piece of paper
 - **Revealing hidden content** using the ESDA technique to recover indented notes (names, telephone numbers, meeting notes) when the top sheet(s) is missing
 - **Demonstrating links between typewritten, printed or photocopied documents**
 - **Revealing alterations in original documents and/or comparing the ink used on them**
 - **Discovering linked cases of malicious communications through use of the Malcoms Database**

Tests and techniques that were sometimes used included:

- **Examination of damaged documents** and reconstruction of documents including those that had been shredded
- **Thin layer chromatography of inks** as this was semi-destructive

Limitations associated with the use of these tests and techniques

- 11.40 Handwriting conclusions were often expert opinions, not definitive identifications. The strength of these conclusions depended on the extent and quality of the material seized and submitted for examination.
- 11.41 Some chemical tests, for example associated with TLC, required sampling that was minimally destructive.
- 11.42 Some chemical reagents affected subsequent examinations, for example it is not possible to detect indented writing or compare inks after treatment with the fingerprint enhancement chemical, ninhydrin.
- 11.43 Identifications from paper/ink can point to probable sources but not always to a named individual without corroborating evidence such as from fingerprints, DNA, and/or witness testimony.
- 11.44 Technology was emerging at a fast pace and machines used to produce documents, for example printers and their characteristics, were becoming more uniform and less variable than traditional machines
- 11.45 In terms of how long testing might take to complete, the actual time for standard general casework is quite short measured in hours or days. For instance, most straightforward handwriting comparisons involving one suspect writing versus writing of one known individual would take in the region of 3-5 hours - to include a report and peer review, and indented impression cases could take 1-3 hours per exhibit depending on whether or not a decipherment of recovered writing or other marks was involved.
- 11.46 But, of course, much would depend on how busy the Questioned Document department was at the time, the extent to which the work might need to be prioritised, the number and nature of the items requiring examination in the case, and availability of staff to do the work.

OBI-Q5c. How were these tests and techniques used practically?

- 11.47 There were wide range of circumstances where forensic document analysis could provide useful to critical intelligence for a criminal investigation and evidence for court hearings
- 11.48 **Handwriting and signature analysis.** These were important tools to link an individual to crime scenes. For example, a signature in a hotel guest book, if genuine, places that individual in that location at a particular time. Letter bombs were often sent in handwritten envelopes and/or with notes inside them. Linking the writing to a common source helped to link incidents together and subsequently to the writer once apprehended.
- 11.49 **Paper and ink comparison.** This was used to determine if documents had been altered, for example to increase the value of a cheque or change the beneficiary, or if entries/pages have been added or removed from documents, erased from pages or obliterated. Examples here would have included altering the expiry date of a document, changing an owner of an asset, hiding or removing areas of text in a diary and substituting pages within Wills, Contracts or other Legal documentation. Any of this could change the status of the document from something legitimate to something fraudulent.
- 11.50 **Examination of printing and typewriting.** This was used to establish if documents were counterfeit and to link scenes together. An example would be a large-scale counterfeit currency investigation where bank notes could be linked to a common origin by defects in the printing mechanism. Subsequent comparison with printing materials found at a scene could associate the counterfeits with the premises and often the perpetrators. Such scenes could also uncover other counterfeit materials and links to larger and more widespread organised crime gangs.
- 11.51 Typewriters were commonly used as the primary source of communication before computer-based printers. They often had unique characteristics and defects which enabled the machine to be associated, conclusively, with documents it had produced. This meant that, prior to the advent of computer based printers (laser/ink jet/thermal), all personal documentation and office correspondence could be linked to the machines that produced them. Ribbons within the machine contained a visible record of everything which had been typed. This not only confirmed that the suspect documents had been produced on that particular machine but provided valuable intelligence about what else the machine had been used for.
- 11.52 It was not uncommon for victims of hate mail to have sent letters to themselves. Examination of their typewriter would help to uncover this. Whilst sometimes a

trivial cry for help, in some instances these letters were the precursor to much more serious events. Examples included ransom notes, and casting blame on others for a subsequent arson on their home. The examinations also greatly assisted in eliminating machines (and individuals) from the production of questioned documents.

- 11.53 **Examination of indented writing.** When one document is written on top of others, the indentations caused by the writing process will be present on the underlying sheet and can be recovered up to five sheets down using the sensitive ESDA technique. A visible image of the indented writing is “lifted” from the document and can be used in a handwriting comparison to address authorship. For instance, it was not unusual for an individual to write a letter that contained their name and address which would be indented on to the sheets below. If those sheets were then used to write an anonymous letter, ESDA testing would recover indentations from the writing on the original letter too.
- 11.54 Before social media and smart phones, anonymous letters were prevalent sources of communication. Case examples include witness intimidation, letters sent in by the public containing information about a crime or claiming to have carried out crimes, and intelligence information (names, addresses, plans etc) for counter-terrorism officers.
- 11.55 The absence of indented writing where you would expect to find it or the presence of unexpected writing can also be of considerable value in an investigation. For example, in a bundle of documents or a diary where entries should be indented sequentially. Indentations evidence could indicate that a page from that document has been removed or another one inserted later. Examples include various documents related to sexual offences where information relating to the history of the offence has been discarded or other information added at a later time. The technique has been used in high profile cases to ascertain if police witness statements have been written when they were supposed to have been.
- 11.56 **Other examinations.** There are a wide range of situations where the examination of documents and the materials used to produce them assist in an investigation.
- 11.57 **Stamp mark comparison.** This is still a widely used technique to address authenticity of documents. Stamps, sometimes associated with a signature/fingerprint, can be fraudulently copied from genuine identity documents/visas etc on to others in the so called ‘identity theft’. These days they are easily and readily lifted from documents using scanners and computer

software to give a level of authenticity to an otherwise fraudulent or counterfeit document.

- 11.58 **Reconstruction of paper and shredded documents** helps the investigation team to recover vital information relating to, for example, a company's correspondence and bank accounts where money laundering from the proceeds of crime is suspected.
- 11.59 **Damaged and burnt documents** retrieval of information is relatively successful using preservation and recovery techniques in addition to analysis using specialised lighting. Examples have included shipping documentation relating to large insurance claims where records have been waterlogged or damaged and the recovery of handwritten and printed details from documents at a scene where arson is suspected.
- 11.60 The examination of folds and creases to a document helps address its history and whether its current state is in keeping with the place and positioning of what it was found in. For example, a letter folded in such a way that it doesn't readily fit back into the envelope it was purported to have travelled in. This can occur when, for example, an individual claims they received a threatening note yet it doesn't fit back into the envelope they said it came in. This has occurred in sexual offence, and witness intimidation cases where the victim has made efforts to elevate a police response.
- 11.61 A whole range of other, non-routine, examinations can assist investigators in solving crimes or help the legal process along in civil cases. A classic example is where a request is made to date the ink used for a signature on a document.
- 11.62 Whilst document examiners do not date inks, it is always worth asking if the document also bears typing. For example, Calibri type font did not enter general circulation until 2007 when it became the default typeface in MS WORD. Many documents dated prior to this but typed using Calibri type font have since been found to be fraudulent. Such an example brought down the Pakistan Government in 2017.

OBI-Q5d. What sort of forensic material, and how much was required for reliable use of the tests and techniques?

- 11.63 Different types and amounts of material were required for each of the different tests and techniques used in document examination, and these have been summarised in the following Table for ease of reference:

Type of Examination	Type of Forensic Material Required	Amount/Quality Needed for Reliable Use	Notes/Comments
Handwriting Examination	Ideally, original handwritten documents, signatures, or notes are best but can work from good quality photocopies	At least 10–15 genuine writing samples covering comparable words, letter forms, and writing conditions	Originals preferred over photocopies; wide range of writing situations increases reliability. Type of pen and substrate used for questioned handwriting can limit what comparisons can be made.
Signature Examination	Ideally, Original signed documents for comparison	Minimum of 12–20 genuine signatures, ideally contemporaneous with questioned item	Pen direction should be visible; photocopies reduce reliability due to loss of stroke detail.
Typewriting Examination	Typed pages, ribbons, carbon copies, and known machine samples	Several pages from the same machine showing a range of characters, spacing, and line alignment	Reliable comparison requires visible individual defects or misalignments; poor-quality copies reduce evidential value.
Printed Document Examination (traditional or digital)	Original printed documents or high-resolution prints	Sufficient area showing consistent print patterns, eg. full lines or blocks of text	Allows identification of printing process (offset, inkjet, laser, etc); minimum area depends on print resolution and quality.
Photocopy Examination	Original photocopy, and comparison copies from suspected machine	Multiple copies from each source to confirm recurring trash marks or defects	At least 5–10 comparative copies ideal for establishing repeating patterns. Evidence may be lost if machine serviced, glass platen cleaned or ink/toner cartridge replaced
Rubber Stamp/Impression Examination	Inked impressions, stamps, and samples taken from suspect stamp	Several clear impressions on similar paper; comparison in identical ink preferable	Worn or damaged stamps improve identification potential; samples taken at same time as questioned stamp impression reduce interpretive uncertainty.
Dry Transfer Lettering/Stencilling	Original lettering samples, sheets, or exemplars	Enough text to assess spacing, alignment, and surface disturbance	Residue or partial transfers must be visible

Type of Examination	Type of Forensic Material Required	Amount/Quality Needed for Reliable Use	Notes/Comments
Alteration/Erasure/Obliteration Examination	Original document with visible or suspected altered areas	Entire document; chemical and lighting tests may require control areas close to the questioned entries	Non-destructive methods used first; reliability depends on contrast between altered and original areas.
Alteration/Erasure/Obliteration Examination	Original document with visible or suspected altered areas	Entire document; chemical and lighting tests may require control areas close to the questioned entries	Non-destructive methods used first; reliability depends on contrast between altered and original areas.
Ink Examination	Original ink entries (ballpoint, gel, or typewriter ribbon)	Minimum 1–2cm of continuous writing; comparison samples from known pens or inks	Visible ink flow essential; destructive tests require sufficient sample to allow repeat analysis. Chemical reagents can affect reliability. Often not possible to compare inks on different papers or different substrates
Paper Examination	Whole sheet or fragment of questioned and known papers	At least one full edge and surface area large enough for fibre, opacity, and watermark comparison	As stock white paper is so common, Reconstruction and comparison success depends on type of paper and printing thereon.
Indented Writing Examination	Original document and several blank sheets from same pad or stack	Entire sheet stack or area beneath questioned writing	Reliable recovery requires minimal disturbance; electrostatic detection (ESDA) used on undisturbed samples. Cannot be carried out after fingerprint testing
Charred/Water-Damaged/Torn Documents	All surviving fragments or sheets	As complete as possible; high-quality imaging improves results	Reconstruction and recovery success depend on extent of damage and preservation before analysis

OBI-Q6. Were there any types of test or technique available between 1 September 1997 and 15 August 1998 believed to be unreliable at the time, but have subsequently been proved to be reliable?

- 11.64 There were no specific tests or types of analysis carried out in the UK between 1 September 1997 and 15 August 1998 that were generally considered unreliable but have since been proven reliable.
- 11.65 There were developments in how printers, photocopiers and fax machines were examined reflecting advances in technology, and this continued throughout the 1990s. For example, it was found in the early 1990s that laser printers and some giant copiers left characteristic marks on the paper. By the late 1990s this was well documented and these marks were being used routinely in casework to link printed documents to each other and/or to a particular machine. The same occurred with ink jet printers and the yellow dot pattern on colour laser printers and colour copiers.
- 11.66 In addition, there were developments in the nineties to show that the temperature and humidity conditions of the room where ESDA tests were being carried out affected the results. However, most laboratories did not change these conditions until after 2000, and there is still on-going debate about the level of enhancement claimed.

OBI-Q7. Were there any types of test or technique available between 1 September 1997 and 15 August 1998 believed to be reliable at the time, but have subsequently proved to be unreliable?

- 11.67 Again, so far as we are aware, there were no tests carried out that were believed to be reliable between 1 September 1997 and 15 August 1998 that have since been proven unreliable. Whilst there were challenges to the admissibility of handwriting evidence in the US in the 1990's, in the so called Daubert hearings, those events in some ways strengthened the use of forensic handwriting evidence in the UK and around the World.
- 11.68 This was achieved through the development of standardised methods, improved documentation, and the adoption of peer review and accreditation systems worldwide, with the introduction of Standard Operating Procedures and best practice manuals such as those produced by the Scientific Working Group for Forensic Document Examination (SWGDOC)¹⁵⁷ and ENFHEX¹⁵⁸. Collaborative inter-laboratory testing exercises were also strengthened worldwide.

¹⁵⁷ <https://www.swgdoc.org/index.php/standards/published-standards>

¹⁵⁸ <https://enfsi.eu/wp-content/uploads/2023/02/BPM-Handwriting-Ed.-4.pdf> (page 10)

INQ038218

Questioned Documents Summary

- 11.69 Around the time of the Omagh Bombing a wide range of questioned document-related tests and techniques were generally available from forensic laboratories across the UK, covering handwriting and signatures, printing of a variety of kinds, paper and inks, and alterations and forgeries involving all of these.

Overall, FSANI appears to have provided a broadly comparable range of forensic services to those available elsewhere in the UK at the time, applying similar tests, techniques and laboratory processes, although the position is less clear in relation to the extent of its access to, and use of databases and other shared resources.

- 11.70 While these laboratories were not accredited in the same way as they are today, there is evidence that quality management systems were in place, and of collaborative inter-laboratory exercises which would show up any discrepancies and/or marked differences in performance between them.

12. OBI-Q8 Forensic Science Laboratories

OBI-Q8a. By whom and where was forensic testing carried out in Great Britain and Northern Ireland between 1 September 1997 and 15 August 1998?

- 12.1 During this period, forensic science services for the 43 police forces in England and Wales were provided by the then six Forensic Science Service laboratories – at London, Chepstow, Birmingham, Huntingdon, Chorley, and Wetherby. The laboratory at Aldermaston had recently been closed, and further closures at Chepstow and Huntingdon were planned – although never actually executed. The Scottish police needs were served by their own four forensic laboratories – at Glasgow for the Strathclyde Police, Edinburgh for Lothian and Borders Police, Dundee for Tayside Police and Aberdeen for Grampian Police, and the RUC in Northern Ireland relied on the Forensic Science Agency Northern Ireland (FSANI) Laboratory in Belfast. *In addition, there were other forensic science laboratories and specialist expertise available to police as described in paragraphs 12.2 to 12.4 below.*
- 12.2 Aside from these, there were several specialist laboratories including the Forensic Explosives Laboratory (part of DSTL) at Sevenoaks for explosives and explosive devices, the Transport Research Laboratory (TRL) at Wokingham for vehicle crash investigations, and Mass Spec Analytical Ltd in Bristol for detecting and interpreting drugs on money. There were also a number of individual specialists – often based in academia, such as Pat Wiltshire for palynology (pollen analysis) and other forms of botanical evidence, Professor Peter French for speech and audio analysis, Dr 'Zak' (Zakaria Erzincioğlu) at Durham University, and Ken Smith of the Natural History museum in London for forensic entomology (insect) investigations.
- 12.3 In addition and reflecting a change in funding arrangements which enabled police forces, at least in England and Wales, to choose from whom to buy their forensic services, a few private laboratories extended their services to police. These included the newly privatised Laboratory of The Government Chemist (LGC) which had been providing forensic services for many years to, for example, HMRC – in relation to drugs of abuse, the Department of Work and Pensions – for Questioned documents, and the Armed forces – for toxicology. To this they had also added DNA analysis to assist with the huge backlogs that had grown in response to demand for the relatively new capability of DNA analysis. *These backlogs had resulted from the increase in DNA sampling from submitted items compared with the speed with which laboratories were able to scale up their operations to deal with them – ie. when demand simply*

outstripped supply causing delays in getting results to investigators. Testing regimes were put in place to deal more quickly with urgent samples, with the rest processed at a slower rate within the backlog. It is not clear whether and to what extent FSANI might have suffered such backlogs at the relevant time¹⁵⁹ although the presence of backlogs was mentioned by the Laboratory Director in his 1997/98 Annual Report and Accounts¹⁶⁰.

- 12.4 Other private firms included Document Evidence Limited – which had been formed after a split of the specialist questioned document team from the FSS, and a new organisation, Forensic Alliance, which had just been established and provided a full range of forensic services in collaboration with Cellmark Diagnostics in respect of DNA, and AEA Technology for a wider range of analytical expertise and instrumentation – as mentioned in Angela Gallop's full CV (**Annex A**).
- 12.5 As the FSS started to lose work to private companies, there was an inevitable decline in its dominance. Having said that, it still had approximately 60% of the forensic market when it was closed in 2012. The other laboratories – in Scotland and Northern Ireland continued much as they had been, working collaboratively with the FSS and increasingly the larger private companies, both scientifically and operationally.

OBI-Q8b. In general terms, what was the role of the Forensic Science Service and the Northern Ireland Forensic Science Laboratory, and of private providers between 1 September 1997 and 15 August 1998?

- 12.6 The role of these laboratories was to provide forensic science services to the police across the full range of activities from crime scene to court. These activities included, for example:
- attendance at crime scenes for on-the-spot advice, and support and guidance about item/sample collection. Depending on the complexity of the case, this could involve a number of scientists across different forensic disciplines
 - providing on-going advice on the best forensic strategies to pursue – both in individual cases and for specific police operations
 - conducting the scientific examination and analysis of items and samples at the laboratory, constantly updating the SIO and his team with latest findings, what they were likely to mean, and ideas for what to do next,

¹⁵⁹ INQ041292 (page 3)

¹⁶⁰ INQ015472 (page 1)

including conducting any experiments to clarify expectations in specific case related circumstances

- assessing and interpreting their scientific results in the context of specific cases - including their observations at the crime scene
- drafting and issuing reports and/or formal witness statements for court, and finally if and as required,
- explaining their findings in more detail to Counsel, providing advice during court hearings, and giving expert testimony themselves.

12.7 On a wider front, forensic scientists would be expected to discuss, particularly with their police customers, emerging trends in criminality and any research and development that might be useful in addressing these, and then carrying out such research and development as appropriate. This could include anything from developing new analytical techniques and methods for better sensitivity and/or discrimination, streamlining processes to improve speed and cost effectiveness, to establishing and maintaining specific evidential databases for more accurate interpretation of the strength of evidence.

12.8 Scientists also played an important role in ensuring that police investigators and their crime scene specialists were trained and kept up-to-date with what forensic science could do for them, and in how to select and collect the most appropriate material from crime scenes and other locations to maximise its potential value to them and their investigations. They were also made aware of the risks of contamination – especially with the development of new, more sensitive techniques in the laboratory, and how to avoid these to prevent compromise to items and samples and any evidence that might be derived from them.

12.9 While the bulk of forensic work was inevitably directed towards the needs of the police, it was also important for the work of these laboratories to be checked and explained and/or challenged on behalf of legal teams representing those accused of crime. This had led to a limited number of mainly small companies, university departments and/or private individuals providing second opinion services. At the relevant time, main firms specialising in this kind of work included Keith Borer Associates Ltd, and Forensic Access. While some of the larger laboratories - certainly the FSS and Forensic Alliance, took the occasional defence case, this did not make best use of their expensive facilities which were better suited to the sort of primary analysis required by the police.

13. OBI – Q9 Standards and Approach in Forensic Science

OBI-Q9a. Was there a difference in standards or approach to forensic testing between Great Britain and Northern Ireland at the relevant time?

- 13.1 From information accessed to date, it is not possible to draw precise comparisons about standards and approach between forensic science laboratories in Great Britain and Northern Ireland, but it seems that the laboratories were all run along similar lines, contained the same sorts of equipment, and had Quality Management Systems underpinned by the same types of protocols.
- 13.2 This is not surprising considering the long history of collaboration between the FSS, and the Scottish and Northern Irish laboratories – both at director and scientist level. Their directors met on a regular basis to discuss general issues, and scientists worked closely together on the technical side of laboratory operations via a series of subject-specific Inter-Laboratory Advisory Committees (ILACs) on which sat representatives of each of the organisations. They also formed subject-specific Working Groups – including with forensic laboratories further afield (see Textile fibres and Questioned documents sections). In addition, the FSS had its own research laboratory – the Central Research Establishment (CRE), which carried out research and development projects, with collaborators in the operational laboratories, academia and/or industry, across a wide range of forensic disciplines.

It is not clear to what extent FSANI had a similar relationship with the Forensic Science Laboratory in Dublin. Beyond some specific references, FSNI says that it 'has no current staff, nor can identify corporate records, to clarify further casework collaboration'.¹⁶¹

- 13.3 When the FSS and the Northern Ireland laboratories were granted agency status – in 1991 and 1996 respectively, their instruments were upgraded in a similar way – see under Textile fibres.
- 13.4 Of course, there were some differences in the profile of criminal activity they were required to assist with, and some laboratories were designated as centres for specific types of examination to concentrate expertise, and this would have been reflected in the capability and capacity of individual laboratories. One obvious example of this was in relation to terrorist bombing and other atrocities of which, in general forensic terms, the Northern Ireland and London/*FEL* laboratories bore the brunt. *While we are not in a position to*

¹⁶¹ INQ041292(page 4)

make direct comparisons between these different facilities, the sheer quantity of explosive devices and associated material examined within the Northern Ireland Laboratory, suggests that the standard achieved was not only satisfactory, but world leading. Dennis McAuley attests to the fact that he personally has been involved in the investigation of over 170 IED incidents which is probably unparalleled globally within a forensic setting.

This *laboratory expertise* extended beyond explosive substances and devices to include related aspects of investigations. For instance, FSANI was recognized as a centre for textile fibre analysis – *undoubtedly partly because textile fibres featured so heavily in providing links between people, locations and objects associated with bombing incidents. More generally, experienced forensic scientists would have developed and honed their significant expertise in their chosen field by working across a wide range of case types, of which in Northern Ireland terrorist bombings were an important and more usual case type. Without doubt, this other expertise would have been shared throughout the Laboratory as work of more junior staff was supported, overseen and developed by more experienced scientists.*

- 13.5 International standards of the type we are used to today for accrediting testing and calibration laboratories were on the horizon but not yet in place. But had there been any marked disparity in general performance between the laboratories, this would be expected to have shown up in inter-laboratory proficiency testing trials, and in reports of independent scientists reviewing the work of individual scientists in specific cases on behalf of the defence.

In relation to general laboratory performance, we do not have sufficient information about, for example, workloads, staffing and resources to make proper comparisons between FSANI and forensic laboratories elsewhere in the UK, and this was not part of our remit. But what we can say is that FSANI staff were obviously working under the most challenging conditions at the time, and for a long time previously, and which included serious and constant threats to their own safety. This is very different from conditions elsewhere in the UK.

OBI-Q9b. Was there written guidance or codes of practice setting out the availability of forensic tests in police investigations and the standards for forensic testing?

- 13.6 On another front, and following in the wake of a series of high-profile miscarriages of justice including the Birmingham 6 pub bombing – mentioned earlier under Explosive substances in which an FSS scientist was heavily criticised about the quality of his work, interest in formal quality management systems began to grow. At first, and certainly in the FSS, these systems were designed internally and featured Standard Operating Procedures (SOPs) for

all the main technical activities in the laboratory. Unlike the Laboratory Manuals which they would gradually replace, these SOPs were mandatory and no longer merely advisory for guidance.

- 13.7 The first organisation to provide third party accreditation was the National Measurement Accreditation Service (NAMAS) which was established in 1985. By 1987, the international standard ISO 9001 was published, providing a framework for ensuring consistent quality in supplying goods and services, and driving continuous improvement. During the 1990s, forensic laboratories were increasingly being accredited to ISO 9001. Then in 1995, NAMAS was superseded by the United Kingdom Accreditation Service (UKAS), and in 1999 a new standard - ISO 17025, was introduced specifically for calibration and testing laboratories – into which category forensic laboratories fell, and a version of this standard is still in force today.
- 13.8 Against this background, by the late 1990s, UK laboratories would be likely to have had some NAMAS accreditation to ISO 9001, but not UKAS accreditation to the ISO 17025 standard which had not yet been introduced.¹⁶² There were separate specific tests which laboratories had to pass in order to be able to supply profiles to the National DNA Database.
- 13.9 The FSS were very active at the forefront of forensic accreditation and influential with ENFSI, and it is likely that this attitude was reflected in forensic laboratories in other parts of the UK as well.
- 13.10 Scientists at the time were concerned to ensure that the same general standards in terms of exhibit handling and avoidance of contamination applied throughout the forensic chain. This extended to the activities of SOCOs and others handling exhibits prior to their submission to the laboratory, and which could otherwise theoretically compromise any forensic evidence found on them. This was particularly important as the scientists developed their ability to detect and analyse ever smaller traces.

OBI-Q9c. Was there a Regulator for forensic science at this time and, if so, in general terms what was their remit?

- 13.11 The Forensic Regulator for England and Wales was appointed in 2007, and their Statutory Powers granted in 2021 – all well after the time period of interest here. However, at the relevant time adherence to Codes of Practice and Conduct tended to be enshrined in laboratory Quality Management Systems and required for membership of relevant Professional Bodies such as the Royal Society of Chemistry, and the Institute of Biology.

¹⁶² *INQ 027071 Witness statement from UKAS CEO about FSANI accreditation*

14. Forensic Science Strategies

OBI-Q10a. To the best of your knowledge, who was responsible for setting the forensic science strategy in a criminal investigation?

- 14.1 Building on the response to OBI Question 2b above, the lead forensic scientist was ultimately responsible for the detailed forensic strategy pursued within the laboratory. But clearly this strategy would be led by the questions that the SIO needed answering – with the scientist translating these into a detailed plan covering which items of those available should be examined, and for what, how these examinations might be prioritized, and what other avenues it might be useful to explore. They would also be responsible for the day-to-day management of the laboratory team undertaking the work and taking into account any funding constraints – both generally, and as they applied to the case in particular as explained by the Force Scientific Support Manager (SSM) in charge of the forensic budget.
- 14.2 The forensic strategy would be constantly evolving as new information became available from other aspects of the police investigation, and results from previous tests continued to emerge from different parts of the laboratory. This meant that the lead scientist had to keep in close contact with the SIO team, attending meetings to discuss and agree best next steps, and ensuring that the associated costs had been pre-authorized. The SIO was expected to keep a close eye on the forensic strategy to make sure that it continued to reflect their needs, and the SSM would work both with the SIO and lead scientist to manage costs.
- 14.3 In large, complex cases, a number of scientists, and scientists with different types of expertise would be likely to be involved in the case – including specialists such as fingerprint experts within the Force, and potentially also involving external specialists in niche areas of expertise from outside the laboratory. Part of the forensic strategy would be directed at deciding the order in which specific tests were to be conducted to ensure that the maximum amount of information was extracted from the testing, and that one sort of test or technique did not compromise the chances of success with another unless absolutely necessary.
- 14.4 In the most serious of cases, scientists might be drafted in from other laboratories to assist the lead scientist and increase the number of pairs of hands available to examine all the items that had been seized
- 14.5 If an investigation had identified a likely suspect and evidence of forensic links with them had been established, then the SIO, in consultation with the prosecution, would decide when to draw a halt to further work. The lead

scientist and perhaps others would then issue a formal statement of evidence to be used in any potential court hearing.

- 14.6 Alternatively, if no scientific evidence had been uncovered linking the suspect with the crime, the scientist(s) would be asked to issue a final report describing what had been done and found, and that this had been the outcome. Occasionally, if a new technique was on the horizon, the lead scientist might suggest that specific items in the case be revisited as and when the new technique had been validated for use.

OBI-Q10b. To the best of your knowledge, how and by whom was the forensic science strategy kept under review?

- 14.7 It follows from the above, and the response to OBI-Q2b, that the forensic strategy would be kept constantly under review – and particularly at points when emerging results might suggest changes in the line(s) of investigation to be pursued or newly prioritised.
- 14.8 If, at any time, the SIO felt that the forensic side of the investigation was failing to progress properly, or wanted a second opinion about the scientific findings that had emerged to date and how they were being interpreted, then they could appoint a specialist scientific advisor to take over the lead for the scientific investigation and inject some new life into it but using the same team of scientists as before. Alternatively, at the relevant time and reflecting the emergence of a market in forensic science, the option of engaging a different forensic services provider altogether was just becoming available.
- 14.9 In any event, the new work would always start with a thorough review of the original scientific investigation(s), and the drawing up of a new forensic strategy for the case. The development of this strategy would then gradually evolve as with an original investigation – with greater or lesser restrictions on the budget available depending, for example, on the complexity and public profile of the case. This type of intervention happened most often when a decision was made by a police force to reopen an old case which had been ‘mothballed’, and was looking for a fresh approach.
- 14.10 Over and above this, there would be regular general reviews of unsolved large cases when forces would tend to ask their own in-force murder review team (if they had one) to review the case. The team would highlight any existing lines of enquiry which might usefully be taken further, or suggest new lines not considered previously or now made possible by advances in approach or technology. This would include scientific aspects of the case and often led to at least some additional focused forensic work.

Concluding Summary

Forensic science encompasses a very wide range of physical traces that individually or in combination can potentially provide objective, speedy and cost-effective links between a perpetrator and their crime. To this extent it is regarded as the cornerstone of any police investigation.

Forensic scientists are responsible for translating an SIO's investigative questions into a detailed forensic strategy covering which items of those available should be examined, for what, and in what order. They are also responsible for keeping the strategy under review and updating it to take account of emerging results and any other new information from elsewhere.

Forensic inputs start at the scene of a crime, and bomb scenes are amongst the most complex of crime scenes, presenting substantial additional challenges to investigators and forensic scientists. In the late 1990s, a wide range of tests and techniques were in use by forensic specialists in forensic science laboratories across the UK including FSANI.

Of immediate relevance were experts in **Improvised Explosive Devices** to identify, often from fragmentary remains in amongst a mass of post-blast debris, how the devices worked and who might have made them, and analytical chemists to identify the explosive substances involved. IEDs consist of five main components and it was the precise nature of these, and how they were joined together – known as the 'bomb maker's signature', that could expose who had made them. The more intricate the device, the greater the chances that it would fail.

At the time, analytical methods to identify **Explosive Substances** focused on nitro-based explosive compounds reflecting the use of these in previous incidents. Methods used at the FSANI Laboratory were generally fit for purpose. They did not include screening for 'other' compounds – from pre-cursor material, which could have been incorporated in the explosive mixture and which might or might not have been able to strengthen any suggested associations with potential sources.

Then there were scientists specialising in personal identification through fingerprints or DNA analysis. So far as **Fingerprints** were concerned, the vast majority of the work carried out in terrorist offences in Northern Ireland would have been dealt with not by FSANI, but by the RUC – with support from the MPS if handled in the same way as similar work in other parts of Great Britain *although there is nothing in the documentary record to suggest this. Unlike the rest of the UK, the RUC did not take more detailed fingerprints (TACT fingerprints) specifically from terrorist suspects which means that some potential links based on fingerprint detail might conceivably have been missed.*

We do know that the introduction of Quality Management Systems in fingerprints lagged behind that in other forensic science specialisms. This was highlighted in 1999 when the role of cognitive bias was exposed as a potentially important factor in fingerprint misidentifications. During the 2000s, considerable safeguards were put in place to help combat this.

DNA Profiling was first developed in the mid-1980s, and by the late 1990s it was becoming a very powerful tool for personal identification. But successful analysis still required a significant amount of DNA in a clearly visible body fluid – such as blood or saliva, to generate a useable result. It was not until the very late 1990s/early 2000s that techniques had advanced sufficiently to be able to detect very small quantities of DNA – such as might be transferred merely through touching. At the relevant time, FSANI's DNA profiling capabilities seemed broadly in line with those in the rest of the UK, and the Laboratory was contributing to a local Northern Ireland DNA Database which, like the Scottish DNA Database, fed into the UK's National DNA Database. *It is not clear whether and to what extent there was any interaction between FSANI and an informal DNA database of crime related material held by the Republic of Ireland.*

Testing for other types of forensic traces could also be very important in bombing investigations. These included textile fibres, marks and chemical traces, and documents the authenticity of which was questioned. In relation to **Textile Fibres**, in the late 1990s examinations were conducted very much as they are today with just as much emphasis placed on finding potentially matching fibres as on analysing and comparing them with potential sources to confirm the matches. FSANI had what appears to have been equivalent facilities to the FSS, and had adopted the 'linking fibres' approach which allowed evidential weight to be attached to matching fibres from two different sources even though no potential source had been identified. This is now in widespread use.

Marks and Chemical Traces included instrument or tool marks, footwear, tyre and manufacturing marks and 'physical (or jigsaw) fits'. Chemical traces covered a wide variety of substances, perhaps most commonly glass particles, and paint flakes. Between them, and individually or in combination, these could provide important, sometimes conclusive, sometimes corroborative evidence in a large number of scenarios including in relation to the assembly of, and planting of bombs. The main forensic laboratories across the UK – including FSANI, appeared to have approached this work in a similar way with only minor differences in protocols between them.

Finally, **Questioned Documents** analysis – covering handwriting and signatures, printing of a variety of kinds, paper and inks, and alterations and forgeries involving any or all of these, was available from forensic laboratories across the UK. This included a small unit within FSANI.

Approaches to forensic work remain generally very similar today although the technology deployed has improved – in some cases, dramatically. These improvements have tended to focus on:

- increasing the sensitivity of testing to allow ever smaller samples to be analysed and compared,
- enhancing discrimination power to enable similar, but not identical samples to be distinguished from one another, and
- introducing a new, more scientific model for evaluating both which forensic tests would be the most useful to perform, and how to interpret the results in the context of each specific case.

These improvements could potentially be reflected in increased strength of evidence of links identified in an original investigation, between items from different places. But, by enabling ever smaller samples to be analysed, comes an increasing risk of potential contamination through inappropriate handling and storage of evidential items, and a number of measures have been introduced to address this. Where the risk remains is when samples from original investigations – collected, handled and stored using procedures in place at the time, are then re-examined using modern, more sensitive techniques.

At the relevant time, all the main UK laboratories appear to have switched from informal Laboratory Manuals providing written guidance, to Quality Management Systems underpinned by Standard Operating Procedures which had to be complied with. These systems have since been developed further and are now underpinned by independent accreditation to International Standards overseen by a Forensic Regulator with the necessary Statutory Powers to enforce compliance with these, and with the Regulator's own separate Codes of Practice and Conduct.

While it has not been possible to conduct a detailed comparison of standards and approach between UK forensic laboratories at the time, they all appear to have been operating in a generally similar way, using the same sorts of instruments with only minor differences in protocols. This is not surprising since the laboratories had been reasonably well connected over a long period of time – both at director, and scientist levels. And had there been any major discrepancies or marked differences in performance, this should have become obvious from, for example, collaborative inter-laboratory proficiency testing exercises, and reviews of individual scientist's work by experts acting for defence legal teams in specific cases.

Statement of Truth

Each contributing scientific group member confirms that he or she understands his or her duty to provide independent evidence and has complied with that duty. All contributing group members confirm that in respect of those parts of the report to which they have contributed: (i) They have made clear which facts and matters referred to in this report are within their knowledge. (ii) Those that are within their knowledge they confirm to be true. (iii) The opinions they have expressed represent their true professional opinions on the matters to which they refer

Signature	Signature
Professor Angela Gallop	Dr Keith Norman
Date: 7 January 2026	Date: 14 January 2026

Signature	Signature
Chris Hester	Kevin Kershaw
Date: 7 January 2026	Date: 7 January 2026

Signature	Signature
Dr Philip Avenell	Roger Robson
Date: 7 January 2026	Date: 7 January 2026

Signature	Signature
Dr Sarah Jacob	Melanie Pugh
Date: 13 January 2026	Date: 7 January 2026

Authors' Professional Backgrounds in Forensic Science

Professor Angela Gallop CBE

Professional Summary

Angela Gallop is one of the UK's most eminent forensic scientists, known equally well for setting up and running full scale forensic science laboratories as for leading the scientific teams responsible for solving so many of the UK's most complex and high profile cold cases.

Angela Gallop's career in forensic science began in 1974 when she joined the **Home Office Forensic Science Service**. She specialised in forensic biology – investigating the full range of assaults up to and including murder, sex crimes, kidnap and extortion and armed robbery. This involved investigating and interpreting crime scenes, conducting and directing the subsequent laboratory work, preparing reports and expert witness statements for the courts and giving expert testimony. The first crime scene she attended was one of the series of murders committed by Peter Sutcliffe – the notorious 'Yorkshire Ripper', who had been terrorising local communities through a series of night killings of women.

In 1986 Angela set up the independent consultancy, **Forensic Access**, primarily to ensure that criminal defence lawyers had access to the same skills and expertise as the prosecution for a better balance of scientific evidence at court. Notable cases included that of Italian banker, *Roberto Calvi*, whose body had been found hanging under Blackfriars Bridge in London in 1982 and where, years after the event, Angela was able to show that he had been murdered rather than had committed suicide.

In 1997, in response to pressure from both police and forensic scientists, Angela co-founded **Forensic Alliance Ltd** – the first independent provider of comprehensive forensic services to investigators and the courts in the UK, and the first independent laboratory to be admitted to the European Network of Forensic Science Institutes (ENFSI). Supported by the engineering and science giant, AEA Technology, Forensic Alliance provided access to a much wider range of scientists and instrumentation, immediately enriching the scientific support available to police investigation. Over the years, Angela established a network of laboratories across the Country including a specialist firearms laboratory within the Royal Armouries at Leeds. She also introduced the new discipline of forensic ecology into mainstream forensic science, helped to professionalise forensic pathology services, and developed and personally oversaw a

new approach to investigating cold cases. This was instrumental in solving a large number of intractable, increasingly high profile historic cases including the murder of *Lynette White* (exonerating the Cardiff 3), *Cheryl Lewis* ('Death on the Nile'), and the killing of *Damilola Taylor*.

In 2005, and in a further bid to enrich forensic science through connection to the wider scientific community, Angela facilitated the acquisition of Forensic Alliance by the Laboratory of the Government Chemist (LGC), creating **LGC Forensics**. She sat on the LGC main Board which extended the range of its forensic services through a series of acquisitions – both in the UK and abroad. Under Angela's direction, LGC Forensics made major contributions to the development of forensic science, improving the timeliness and cost effectiveness of services, and introducing innovation particularly in DNA analysis. She was also instrumental in LGC's continuing success with high profile complex cases including the murders of *Rachel Nickell* (exonerating Colin Stagg), and *Stephen Lawrence*, and the *Coastal Path murders* and related crimes, for which she received personal commendations. (More recently LGC Forensics was acquired by Eurofins and remains the largest supplier of independent forensic services in the UK.)

In 2010, Angela co-founded **Axiom International Ltd** (now TAG International Ltd). Using its powerful and unique blend of policing and forensic science expertise, Axiom specialised in helping law enforcement agencies overseas – particularly in fragile and conflict-affected states, to improve their forensic science and policing structure in support of global criminal justice and national security. Later, the Company's services were extended to include advocacy and Rule of Law for end-to-end support across whole criminal justice systems. Under Angela's guidance, Axiom trained scores of scientists across the full range of forensic disciplines, including through a ground-breaking partnership with the University of Huddersfield which uniquely combined academic rigour with operational training. Axiom also used its special forensic science skills and expertise to help solve complex cases in other jurisdictions. Accompanying and facilitating this, the Company designed, constructed and/or fitted out new laboratories, police facilities and court buildings.

She is a Past President of the Forensic Science Society – now the Chartered Society for Forensic Sciences, was a founding member of the Governing Council for the Registration of Forensic Practitioners, and has assisted universities in various roles including Strathclyde University which has the oldest and one of the most distinguished academic centres for forensic science, and where she is currently Visiting Professor.

She has been invited representative of independent forensic science to various Government committees, in the private deliberations of the Royal Commission on Criminal Justice, and she was a commissioner on the Independent Police Commission chaired by Lord John Stevens. She has been invited to comment on forensic science issues on television, radio and in the Press, and written extensively about the use and misuse of forensic science within the UK criminal justice system. She has also been an invited speaker to numerous scientific, legal and lay audiences.

Angela's academic qualifications include Bachelor of Science (Sheffield University) and Doctor of Philosophy (University of Oxford) degrees, and she has also been awarded three honorary doctorates – one of Civil Laws (Northumbria University) and two of Science (Nottingham Trent and Sheffield Universities). She is a Chartered Biologist and was elected Fellow of the Royal Society of Biology, and Royal Society of Arts, and she was awarded the CBE for services to forensic science in the 2015 Queen's Birthday Honours.

Angela continues to provide advice and guidance to the UK criminal justice system by devising strategies for the police, CCRC, and families of people affected by crime – either as victims or where they believe there has been a miscarriage of justice. She writes books and contributes to films to improve public understanding about forensic science and promote better decisions about its use and, as part of this, she co-chaired the Westminster Commission on the Role of Forensic Science in Miscarriages of Justice which reported in June 2025.

Summary of Academic Qualifications and Awards

- Bachelor of Science (BSc) Sheffield University 1971, JB Boswell memorial Prize
- Doctor of Philosophy (DPhil) University of Oxford 1975
- Chartered Biologist (CBiol) and (elected) Fellow of the Society of Biology (FSB) 1990
- (Elected) Fellow of the Royal Society of Arts (FRSA)
- (Elected) President of the Forensic Science Society 2003
- (Honorary) Doctor of Civil Laws (DCL) Northumbria University 2008
- Visiting Professor – Northumbria University 2008 - 2012
- (Honorary) Doctor of Science (DSc) Nottingham Trent University 2011
- Fellow of the Forensic Science Society 2013
- Awarded CBE for services to forensic science in the 2015 Queen's Birthday Honours
- Director of Strategy - Centre for Forensic Science, University of Strathclyde 2016 - 2020
- (Honorary) Doctor of Science (DSc) Sheffield University 2017
- Visiting Professor – University of Strathclyde 2020 – current

Academic Publications

- **2013:** *Criminal Justice, Science and the Marketplace: The Closure of the Forensic Science Service in Perspective. Featured in The Journal of Criminal Law – Volume 77, Issue 1 (pp 56-77) Tim Wilson & Angela Gallop*
- **2014:** *The Market Future for Forensic Science Services in England and Wales Policing - Angela Gallop & Jennifer Brown- Policing UK Magazine 8 (3): (pp 254-264)*
- **2014:** *Regularising the Regulator: the Government's Consultation about Placing the Forensic science Regulator on a Statutory Footing (joint author) Michael Stockdale, Angela Gallop, Bill Lawler- The Journal of Criminal Law JCL 78 (2). (pp 136-163)*
- **2018:** *Re-examining the 'reliability' of forensic pathology evidence; Wilson, Tim J.; Jackson, Adam; Gallop, Angela; Piasecki, Emma; - Forensic Science Evidence and Expert Witness Testimony (Chapter 6), ISBN No: 9781788111027*
- **2018:** *Clarifying the 'reliability' continuum and testing its limits: biometric (fingerprint and DNA) expert evidence - Sophie Carr, Angela Gallop, Emma Piasecki, Gillian Tully, Tim J Wilson - Forensic Science Evidence and Expert Witness Testimony, Chapter 5 (pages 155-183) - IBAN No. 9781788111034 (electronic)*

Other Articles- invited by eg:

- Journal of the Forensic Science Society
- Legal Aid News
- Criminal Bar Association Newsletter
- Chemistry in Britain
- The Barrister Magazine
- New Law Journal
- Science and Public Affairs Magazine
- Public Servant Magazine
- Policing Today
- Policing UK Magazine

Keith Norman

Professional Summary

Keith is an internationally recognised scientist with 30+ years of experience specialising in forensic science and the application of intelligence generated to enhance operational outcomes. Keith has broad practical, theoretical and research experience with proficiency in a wide range of areas of chemistry (including toxicology, environmental chemistry, illicit drugs, physical evidence, crime scene operations and chemical warfare agents). Keith is also a recognised international expert in the areas of illicit drugs and chemical warfare agents. With significant experience and proficiency in international capability building by mentoring and training.

An experienced leader and mentor of diverse, multi skilled and multi-cultural teams. He has extensive project management experience in domestic and international settings. He is also experienced in identifying funding opportunities and submitting successful proposals.

Established, developed and maintained extensive domestic and international professional networks for the exchange, collection and/or dissemination of information.

Skills

- Scientific research and technical writing
- Mentoring and developing high performing teams
- Creative team leadership focusing on strong team culture and cohesiveness
- Project management
- Development of project proposals and budgets
- Critical review of information, systems and processes for continuous improvement
- Developed of stakeholder relationships
- Development of training materials and exercises
- Incident response
- Computers, both software and hardware applications
- Instrumental analysis
- Lecturing and public speaking
- Development of forensic intelligence capabilities

Professional Experience

January 2018 – Present

Consulting Scientist, Forensic consultant (self-employed), Perth, Australia

September 2024 – Present

Lead Analytical Chemist - Australian Submarine Agency, Perth, Australia

May 2024 – September 2024

Executive Advisor - Forensic Science Queensland, Brisbane, Australia

January 2023 – January 2024

Scientific Affairs Officer, United Nations Office on Drugs and Crime (UNODC), Bangkok, Thailand

August 2022 - January 2023

Technical Manager, Liquid and Technical Services, Cleanaway Australia, Kwinana, Australia

October 2019 – November 2022

Part time Consulting Scientist, GHD Australia, Melbourne, Australia

November 2019 - November 2022

Part time Consulting Scientist, EPE Australia, Brisbane, Australia

November - 2019 – October 2021

Scientific Affairs Officer, United Nations Office on Drugs and Crime (UNODC), Kabul, Afghanistan

July 2018 – November 2019

Scientist, Leidos Australia, Melbourne, Australia

July 2017 – December 2018

Consultant – Counternarcotics Intelligence and Drug Forensics Expert, United Nations Office on Drugs and Crime (UNODC), Kabul, Afghanistan

June 2012 to June 2017

Senior Scientist & Research Officer (Emergency Response), ChemCentre, Perth, Australia

November 2006 – June 2012

Chemical Warfare Advisor, Australian Federal Police, Canberra, Australia

June 2004 – November 2006

Court Reporting Forensic Scientist, LGC Forensic, Oxfordshire, United Kingdom

April 2003 – June 2004

Scientific Officer Crime Scene, Australian Federal Police, Canberra Australia

February 1997 - April 2003

Forensic Chemist & Research Officer, ChemCentre, Perth, Australia

Education

- **Cranfield University, Shrivenham, United Kingdom**
- **University of Western Australia, Perth, Western Australia**
- **Curtin University of Technology, Perth, Western Australia**
- **Edith Cowan University, Perth, Western Australia**
- **Australian Institute of Management, Perth, Western Australia**
- **Doctorate (Defence and Security), 2020**
- **Master of Science (Clinical Biochemistry), 1992**
- **Bachelor of Science (Chemistry), 1989**
- **Graduate Certificate (Computer Security), 2008**
- **Diploma (Project Management), 2014**

Professional Memberships

Royal Australian Chemical Institute	Fellow and Chartered Chemist (FRACI, CChem)
Royal Society of Chemistry	Fellow (FRSC)
Clandestine Laboratory Investigating Chemist Association	Associate (CLIC)
Chartered Society of Forensic Sciences	Member (MCSFS)

Chris Hester

Professional Summary

Chris Hester is a highly skilled professional with 23 years of expertise in counterterrorism operations, specialising in bomb scene investigation and chemical, biological, radiological, and nuclear (CBRN) hazards. Chris possesses extensive operational experience and has consistently demonstrated innovation in developing cutting-edge tactics and techniques based on his experience. Proficient in all aspects of counterterrorism search operations, including team leadership, search control, explosive trace detection, X-ray operation, and technical counter surveillance measures, Chris also possesses comprehensive Geographic Information Systems (GIS) skills.

A highly experienced bomb scene investigator with multiple commendations, with the ability to uncover critical information and resolve complex cases through his keen analytical skills and methodical research. A respected counterterrorism trainer, both in the UK and internationally who can conduct training needs assessments, develop lesson plans, training syllabi, and deliver both practical and theoretical lessons. Chris excels communicating with policing partners of all ranks as well as external stakeholders

Skills

• Advanced Car, 4X4 (on & off road) & LGV Driver • Advanced Forensic Photographer • Bomb Scene Management • Bomb Scene Investigator • Chemical, Biological, Radiological & Nuclear (CBRN) Forensics • CBRN Search Instructor • COSHH Assessor • Counter Terrorism (CT) Search Team Leader • Exhibits Officer • Explosive Trace Detection Operator • Foreign & Commonwealth Office (FCO) Technical Counter Surveillance Measures (TCSM) • Hazardous Environment Awareness Training (HEAT)	
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• Health Protection Agency (HPA) • Radiation Protection Supervisor (RPS) • Level 4 Working at Heights • Medium Risk Confined Spaces • Marauding Terrorist Attack (Op Plato) • National CBRN Instructor • Specialist Risk Assessor • X-Ray Operator	
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Employment History

November 2014 – 30 November 2025

SO15 Police National Bomb Data Centre, Metropolitan Police Service

- Lead investigator, 2017 Manchester Arena bombing.
- Lead investigator for 2017 Parsons Green bombing
- Lead investigator, 2021 Liverpool Women's Hospital bomb.
- Specialist forensic support for the 2017 Westminster Bridge, 2019 London Bridge and 2020 Streatham attacks.
- Police representative on the NPSA Materials & Characteristics Working Group.
- UK representative (and appointed as Forensic Advisor) on the International Bomb Data Centre Working Group (IBDCWG).
- IED advisor to the UK Police Explosives Detection Dogs Working Group.
- Bomb Scene Investigation instructor on Bomb Scene Management courses both in the UK and overseas (Nigeria, Cameroon, Indonesia, Philippines, Bangladesh, UAE and Europol (Hungary)).

February 2011 - November 2014

SO20 CT Specialist Search Team, Metropolitan Police Service

- Responsible for liaising with LOCOG, venue operations managers & producing venue CT search plans for the London 2012 Olympics.
- Designed and co-ordinated the Olympic CBRN profiling operation.
- Designed and co-ordinated the explosive detection search element of the Glasgow 2014 Commonwealth Games.

- Search Controller/Team Leader on numerous major searches including landfill sites, high-risk missing persons and CBRN.

August 2006 - February 2011

CBRN Instructor, Metropolitan Police Service

- Designed and delivered CT specific CBRN training.
- Co-authored the police CBRN Search manual and Course.
- Worked closely with DSTL Porton Down and AWE to deliver training to SRT team members.
- R&D work with MPS Forensics in DNA and fingerprint recovery from contaminated scenes.
- Additional operational support role as a CBRN Search Team Leader and Guardian Purple (Royalty) emergency CBRN extraction team member.
- Appointed as the Radiation Protection Supervisor for MPSTC.

March 2002 – August 2006

SO13 Anti-Terrorist Branch Specialist Search Team, Metropolitan Police Service

- Involved in a number of high-profile CT investigations including 7/7 and 21/7 London bombings.

June 2000 – March 2002

PC, Divisional Intelligence Unit, West End Central, Metropolitan Police Service

- Established and ran remote observation posts to support local surveillance operations.
- Processed and developed criminal intelligence for both uniform frontline and CID units.

March 1996 – June 2000

Uniform PC, general policing duties Vine St/West End Central, Metropolitan Police Service

- First officer on scene, Admiral Duncan Pub bomb in 1999.
- General front line response policing duties including L2 Public Order, Public Order Medic, Officer Safety Instructor & CT Search Team.

November 1995 – March 1996

Hendon Police Training College, Metropolitan Police Service

Education

November 2020

MSc, Forensic Explosive and Explosion Investigation, **Cranfield University**

March 2015

Certificate, Terrorism Studies, **St Andrews University**

July 2010

NVQ level 3, Direct Training and Support, Oxford Cambridge and RSA Examinations
(OCR)

Professional Memberships

- Member of the Chartered Society of Forensic Science
- Member of the International Association of Bomb Technicians & Investigators
- Technician of the Institute of Search and Technical Rescue
- Former member of the Institute of Explosives Engineers

Kevin Kershaw**Professional Summary**

Kevin has over 45 years' experience working in forensics at an operational and strategic level both in the UK and overseas which has included Afghanistan, Somaliland, Iraq, Kurdistan, Jordan, The Gambia, Senegal, Nigeria, Kenya on behalf of UK, USA, Italian, French and German Governments.

With particular reference to time spent overseas, this work has predominantly focussed upon counter terrorist forensic support including establishing forensic services, training personnel and developing counter terrorist forensic provisions and strategies to support the requirements of the respective countries' agencies and the sponsoring governments.

Skills

Current Roles – Independent Forensic Management and Training Consultant and Independent Fingerprint Expert with over 41 years experience as a reporting officer during which time I have produced hundreds of evidential reports and provided expert testimony at all levels of court in the UK including the Royal Court of Appeals.

Retired from UK Police Service after 33 years at Greater Manchester Police in 2012 as Head of Forensic Identification Services being responsible at that time for the delivery of services which included Fingerprints, Footwear, DNA, Laboratory Services, Digital Forensics, Forensic Exhibit submissions and Forensic Intelligence management within the Greater Manchester area.

At the North West Regional level, was responsible for the Regional Counter Terrorist Fingerprint provision and was a member of the Mass Fatalities/ Regional Resilience group.

Both in 1992 and 1996, as a consequence of Manchester city centre being bombed by the Provisional IRA, Kevin was seconded to the Metropolitan Police Terrorist Fingerprint Department at New Scotland Yard to support the investigation.

These secondments required working directly with their in-house Terrorist Fingerprint team of experts at NSY over many months, carrying out the same duties of this team which included checking suspects against crime scene marks recovered from both the initial bombing sites and all scenes that could be linked in some way to the incident, or suspects believed to have been involved. There was also a requirement to search any scene marks against known terrorist suspects and wider fingerprint databases and meticulously documenting all results before reporting to the investigative team.

In 2007 seconded to UK Home Office/UK Police Service for two years as an SME reviewing the UK Forensic provision to consider improved ways of delivering Forensic Services nationally.

During this time conducted a Health Check of all current National forensic projects (eleven in total) making recommendations in terms of which projects should be supported and which should be either suspended or stopped.

Additionally reviewed all UK Police Forensic departments in terms of the potential to work collaboratively and later produced a report "*Organisation and Structure of Police Forensic Services*" which evaluated the benefits of collaborative working within forensics across the UK.

Both in 1992 and 1996, as a consequence of Manchester city centre being bombed by the Provisional IRA, Kevin was seconded to the Metropolitan Police Terrorist Fingerprint Department at New Scotland Yard to support the investigation.

These secondments required working directly with their in-house Terrorist Fingerprint team of experts at NSY over many months, carrying out the same duties of this team which included checking suspects against crime scene marks recovered from both the initial bombing sites and all scenes that could be linked in some way to the incident, or suspects believed to have been involved. There was also a requirement to search any scene marks against known terrorist suspects and wider fingerprint databases and meticulously documenting all results before reporting to the investigative team.

Education

2012 - Manchester Metropolitan University, Manchester
Post Graduate Diploma: Strategic Management & Change

2009 - Lucidus Consulting
APM Project Risk Management Level 1

2009 - Lucidus Consulting
APM Project Risk Management Level 2

2008 - Lucidus Consulting
APM (Association of Project Management) Project Management

July 1984 - New Scotland Yard London

UK Police & Government Fingerprint Expert and Crime Scene Examination to advanced level.

Professional Memberships

Active Member of several National Forensic Groups between 2007 – 2012 including:

- Member of National Fingerprint Board
- Chair of National Fingerprint Training and Evaluation Group
- Deputy Chair of National Footwear Board
- Member of the Forensic Science Training & Standards Group
- Member of the Forensic Science Competency Project Board
- Member of the National Occupational Standards for Forensic Science Group (Skills For Justice)

Dr Philip Avenell**Professional Summary**

Philip Avenell is a forward-thinking, determined and adaptable leader with a strong scientific background, extensive quality management expertise, and significant experience in forensic science leading reviews on behalf of both the prosecution and defence. Known for a keen attention to detail, strong problem-solving skills, and a drive to understand, develop and successfully manage projects to deliver target goals.

Experience**2023-Present - Self Employed
Independent Science and Operations Consultant**

Delivering training, facility design, quality systems, validation and accreditation advice, in-country support and casework reviews to government agencies, private clients and businesses.

Commissioner on the Westminster Commission inquiry on Miscarriages of Justice.

**2018-2023 - Forensic Access
Operations and Science Director (SME)**

Managed a complex team structure delivering a range of scientific work packages under ISO17025 accreditation, leading in quality, new business, and infrastructure development as well as the day-to-day running of the business (approximately 45 staff and growing to become part of group of over 150 employees).

- Management, co-ordination and delivery of forensic investigation and review work for current and historical case reviews.
- Project management in a variety of areas including science research, infrastructure implementation and new product design and service delivery.
- Led Research and Development portfolio, scanning for new technologies and delivering advancements in forensic science services.
- Conducted reviews of processes and systems to enhance efficiency and maintain quality.
- Produced management information and responsible for profit and loss accounts, presenting at board level.

- Managed due diligence, data rooms and technical reviews during mergers and acquisitions.
- Led the design, fit-out and relocation of the company premises, ensuring ISO accreditation was maintained along with a continuous workflow.
- Handled facilities management, including building contract negotiation and functionality assurance.
- Oversaw and delivered technical reviews assessing third-party laboratory setups, quality management and process delivery of facilities both in the UK and overseas.
- Advanced IT infrastructure and project management focusing on data handling, reporting and security.
- Co-ordinated with clients and commercial teams during bid management and establishment of contracts for new business streams and establishing new departments.
- Responsible for HR and recruitment until a full time HR team was established and leading on a project to establish pay policy and career structure.
- Led organisation design and supported team and personal development.

2011-2018 - Axiom International/Forensic Access**Principal Scientist**

A member of the SMT, running a range of projects and providing technical expertise while managing the expectations of stakeholders.

- Applied specialist knowledge to complex scientific reviews to develop new strategies and workflow plans.
- Project management of a range of multiple, concurrent projects including setting up a DNA testing facility, supporting validation and delivering ISO17025 and associated accreditation.
- Developed ideas and delivered new business projects both internally and to external clients in the UK and overseas.
- Provided technical support and process development to an external organisation for a Home Office sponsored project to deliver specialist forensic services.
- Developed and maintained accredited processes under ISO 9001, 17025 and 17043.
- Communicated complex theories and findings to a wide range of audiences, including legal professionals and the media in the form of documentaries and news broadcasts.
- Presented as an expert witness in Courts of Law and provided professional development presentations for legal professionals.
- Provided technical training and mentoring for delegates from the UK and overseas.

- Managed and progressed Research and Development grant applications and projects.
- Maintained facilities and complete IT infrastructure to support business needs while adhering to accredited processes.
- Oversaw the facility infrastructure for the merger and subsequent separation of businesses.
- Managed the identification and implementation of various software applications for instrumentation use and CRM application.

2005-2011 - LGC Forensics**Science Lead – Biology Department****Research and Development Implementation Manager****Reporting Officer - Lead Scientist, forensic biology**

A senior scientist carrying out complex casework alongside roles in senior management to progress the business in a changing forensic industry.

- Supervised and led complex forensic investigations managing teams and leading on the biology and DNA aspects of the casework.
- Maintained and developed the quality of biology casework in a changing industry through protocol and structure improvements.
- Supported and developed ISO 17025 accreditation and scientific output quality.
- Led team development focusing on individual progression and improving efficiency through refined processes.
- Managed the research and development portfolio.
- Recruited to manage an ongoing large research project looking into a novel approach to forensic analysis – responsible for assessing progress and developing a stop/go strategy.
- Implemented project ideas into existing processes, introducing novel technologies to improve examination quality and productivity.
- Worked as part of the team, participating at all levels and able to adapt to all roles to ensure a task is completed to the best outcome.
- Generated new protocols to ensure robust processes fit for purpose and presentation within the England and Wales legal system.
- Line managed a team of scientist performing a range of roles.

2002-2005 Forensic Science Service**Reporting Officer – Biology and DNA profiling**

A forensic reporting biologist working within the homicide team based in the London laboratory working predominantly for the Metropolitan Police Service.

Education

1998-2001 University College London: Ph.D. Biochemical Engineering

1997-1998 University College London: M.Sc. (Distinction) Bioprocessing

1993-1996 University of Leeds: B.Sc. (Hons) II(i) Applied Zoology

Acknowledgements

Chief Constable's Commendation (2011), Dyfed Powys Police

for forensic science services and expertise in advancing the investigation and presentation of the findings at court.

Acknowledgements for professionalism and delivery of complex scientific issues as an expert witness aiding counsel and courts and delivering presentations.

Roger Robson

Professional Summary

Roger spent 20 years as a career scientist in the Forensic Science Service (FSS), working in both the Biology and Chemistry sections. Roger became the Laboratory Fibre Specialist at the FSS Wetherby Laboratory and then Head of Analytical Services there by 1992. He continued to specialise in crimes that involved trace evidence (fibres, hairs, glass, paint among others) giving expert evidence in criminal courts across the UK. He was a founder member of the European Fibres Working Group, part of European Network of Forensic Science Institutes (ENFSI), at its inception in 1994. He sat on the Steering Committee, gave annual presentations on forensic investigations involving fibres, and co-authored the first Manual of Best Practice for Fibre Examinations. By 1996, He was the FSS's co-lead on textile fibres which involved inter-laboratory collaboration of methods and proficiency tests across the UK.

In 1998 he left the public sector to join Forensic Alliance Ltd., where he became Head of Operations in 2002. He led the implementation of the current international quality standard for laboratory based forensic science, ISO 17025. By 2003, the company was acquired by LGC Forensics Ltd. where he then became Head of Homicide Investigations until leaving in 2007. During this period, he worked directly on several high-profile cases involving textile fibres.

From 2007-2017 Roger was the Managing Director of Forensic Access Ltd. where he again led the implementation of ISO 17025 and ISO 17043. During this time, he was directly involved in a National Security project for the Home Office/MoD to design and build a unique analytical facility to cater for a radio nuclear forensic samples. This project involved designing unique instrumentation and close collaboration with other key agencies both in the UK and overseas, and engagement about sensitive security issues at the highest Ministerial level. Roger also continued to focus on unsolved homicides and appeal cases involving textile fibre evidence – some of which are detailed later.

From 2010-2019 Roger was invited to join the Forensic Regulator's Advisory Council. He was the only practising forensic scientist on the Council. Since 2017, he has run his own consultancy where he has continued to attract cases involving trace evidence internationally. In 2019 I was appointed Visiting Professor at Staffordshire University.

Most recently, Roger was approached by the United Kingdom Accreditation Service (UKAS) to take up a new role as their Trace Specialist. This involves auditing forensic service providers in the UK and giving general advice on forensic science to UKAS.

Forensic Case highlights: Roger has been directly involved in many high-profile criminal cases and has given evidence in seven countries. A snapshot includes:

- Advising lawyers representing Barry George in his retrial for the murder of Jill Dando.
- Being instructed by Sussex Police to re-evaluate the forensic evidence, prior to trial, in the murder of Sarah Payne after a catalogue of errors had been unearthed by the defence. This involved re-testing various elements of the case and uncovering new fibre evidence. In conjunction with the original FSS results, Roy Whiting was convicted in 2000.
- Leading the textile fibres work in the incredibly complex re-investigation of the Coastal Path murders, and related murder and assault cases, of which John William Cooper was suspected. The original forensic work had been reviewed many times by different forensic providers/experts yet the crimes remained unlinked and unsolved. Roger's work uncovered a myriad of textile fibre links, and also led to the discovery of critical DNA evidence. Cooper was found guilty on all counts in 2011. Roger was awarded a Commendation by the Chief Constable of Dyfed Powys Police.
- For Suffolk Police in the Simon Hall Appeal case, acting as forensic arbiter between two respected experts whose opinion differed about the proposed match of a population of fibres found on the deceased, and a similar population within the home of the suspect – for which a source(s) had never been found. The fibre populations had played a key role in the first conviction. Roger reviewed in detail the work of both experts and on this occasion considered that the work undertaken by the prosecution expert was safer. The Judges agreed and the conviction was upheld.
- Being instructed in 2017 on behalf of Bradley Edwards who had been accused of killing at least three women – the Claremont Serial Killings, in Perth, W. Australia. Roger's work spanned 18 months, and the trial lasted 8 months before Bradley was found guilty in June 2020.

Publications

Roger has published various book chapters and scientific papers during the course of his career, and presented at many scientific conferences internationally. Highlights related to trace evidence include:

- ENFSI: co-author of the first ENFSI publication: *European Guidelines for the Forensic Examination of Textile Fibres* in 2001; 2nd Edition 2011 and referral 2022.

- The Royal Society: *Forensic Science in Practice* - as part of the Chief Scientist's Advisor Report to the Government. 2016.
- Royal Society of Chemistry: *The Use of Light in Forensic Glass Analysis*. Co-author 2017
- Bloomsbury: *Mason's Forensic Medicine & Law*. Co-author 2023

Dr Sarah Jacob DPhil BSc (Double Hons)**Professional Summary**

A highly competent Consultant Forensic Scientist with over 24 years' experience in marks and trace evidence, having successfully dealt with numerous high profile complex cases including review of cases for the Court of Appeal. A very experienced lecturer and trainer in forensic science who has taught at a number of universities and has devised and delivered numerous training courses for Crime Scene Investigators, police, HM Armed Forces and foreign law enforcement agencies.

Skills & Achievements**Forensic Science Casework**

- Very experienced in a wide range of marks (footwear, tyre, glove and damage marks) and trace (glass, paint, lachrymators, sexual lubricants and other chemical and particulate traces) evidence including 'unusual' evidence types and cases.
- Recognised as highly skilled in the assessment, strategy setting, laboratory examination and detailed interpretation of complex cases. Successfully dealt with numerous cases, including complex murder and other serious high profile cases, incorporating joint examinations with other evidence types. Worked on behalf of both prosecution and defence including review of cases for the Court of Appeal.
- Successfully carried out scene examination at high profile crime scenes including recovery of footwear mark evidence
- Provided clear and concise presentation of results as statements and orally at Court including high profile murder cases at the Central Criminal Court (Old Bailey). Evidence was clearly presented in terms understandable to the layman whilst maintaining scientific accuracy.
- Worked collaboratively with management of cases through a team, including the provision of file reviews and quality assurance checks for colleagues.
- Committed to providing quality forensic science. Involved in the preparation of quality documentation surrounding the examination of footwear mark evidence to achieve UKAS accreditation.

- Worked in collaboration with police to design and implement the creation of a Ground Truth Data Collection relating to footwear mark evidence to comply with Forensic Science Regulator requirements.

Training

- Designed and delivered training courses for Crime Scene Investigators, police forces, SO15 Counter Terrorism Command and HM Armed Forces, resulting in an improved quality in forensic submissions with excellent feedback received.
- Consistently delivered high quality lectures to forensic science BSc and MSc students covering analytical techniques and marks and trace evidence with excellent feedback received on the engaging delivery style. Created collaborative research projects with University Forensic Science Departments.
- Regularly gave articulate and interesting presentations to the media – interviews broadcast on BBC Radio 1 and Radio 4 and BBC1's 'Bang Goes the Theory' and 'Murder, Mystery and My Family'.
- Undertook a project in conjunction with Geos International Consulting Ltd at the Laboratory of the Government Chemist, Nairobi, Kenya to provide in-depth training to forensic scientists.
- Contributed a chapter on trace evidence for the latest edition of the Royal Society of Chemistry textbook 'Crime Scene to Court: The Essentials of Forensic Science' published 2024.

Career Summary

Forensic Consultant (2023-Present)

Dr Sarah Jacob Forensic Consultancy

Senior Forensic Scientist Forensic Access Ltd (2013-2023)

(formerly ArroGen Forensics Ltd and Manlove Forensics)

Lecturer in Forensic Science (2023-Present)

Kingston University

Lecturer in Forensic Science (2017-Present)

King's College London

Lecturer in Forensic Science (2010-Present)

London Metropolitan University

Lecturer in Forensic Science (2013)

University of the West of Scotland

Lecturer in Forensic Science (2013)

University of Abertay, Dundee

Lecturer in Forensic Science (2006-2012)

London South Bank University)

Forensic Trainer - Kenyan Government Chemist Laboratory - Nairobi (2012)

Geos International Consulting Ltd (2012)

Geos International Consulting Ltd

Senior Forensic Scientist (2005-2012)

Forensic Science Service Ltd

Forensic Scientist (2001-2005)

Forensic Science Service Ltd

Qualifications And Training

Post-Doctoral Research Associate - Arizona State University, Department of Chemistry and Biochemistry, Tempe, Arizona, USA

DPhil, Physical Chemistry - Christ Church, University of Oxford, UK - CASE (Collaborative Award in Science and Engineering) studentship awarded by Shell UK Ltd

BSc (Double Hons), Chemistry with Professional Training - Registered Forensic Practitioner (CRFP) from 2003 to close of CRFP in 2009 - Awarded the Institute of Leadership and Management (ILM) Endorsed Award for Trainer Skills

Infrared Spectroscopy Training Course run by Infrared and Raman Spectroscopy Consultants Geoffrey Dent and John Chalmers

ENFSI training course Quantitative Analysis of Glass Fragments

ENFSI training course Microscopic Examination of Paint Fragments

Melanie Pugh BSc. (Hons) Analytical Chemistry MCSFS**Professional Summary**

Forensic Scientist specialising in handwriting and questioned documents.

Melanie has examined thousands of documents and dealt with many legal cases both simple and complex. She is a senior court reporting scientist and has given expert witness evidence on many occasions. She carries out work for prosecution authorities, including police forces, The Crown Prosecution Service and Government departments.

Melanie is an experienced expert witness in civil litigation casework in the UK and overseas and has produced numerous reports compliant with civil rules procedures. She also acts as a single joint expert.

Areas of Expertise

- Handwriting examinations
- Signature authenticity
- Forgery
- Disputed documents
- Altered documents
- Printed documents
- Experienced expert witness

Career Summary

UK Home Office - undertook an extensive training programme within the UK Home Office Forensic Science Service, to become an expert specialising in the scientific examination of handwriting, signatures and disputed documents. She also specialised in the chemical analysis of inks.

European Network of Forensic Science Institutes (ENFSI) - was part of the European working group for document examiners (ENFSI), which included writing best practice manuals and organising international conferences.

Stockton Pugh - now an independent Forensic Scientist as part of Stockton Pugh, and a member of the UK Chartered Society of Forensic Sciences.

Legal Experience

CV Highlights

- Forensic Scientist with over 20 years' experience.
- Highly respected expert in all aspects of document examinations, including signature comparison, handwriting analysis and the forensic examination of questioned or disputed documents.
- Highly experienced in offering critical evidence in some of the UK's most high-profile and complex cases.
- Vastly experienced senior court reporting scientist having presented evidence on numerous occasions.
- Highly skilled in the utilisation of detailed observational methods to analyse documents in order to determine authenticity and detect forgery.
- Trained at the Home Office Forensic Science Service.
- Provided speciality training to police forces, government departments and banks.
- Trained and professionally developed Forensic Scientists in the UK and overseas.

Melanie was recently engaged by the Thai Embassy to train personnel from the Forensic Science Institute in Thailand.

- Registered Forensic Documents and Handwriting Expert with the former UK government's Council for the Registration of Forensic Practitioners.
- Secretary of the working group for forensic document examiners within the European Network of Forensic Science Institutes (ENFSI) (2008-2011).
- Working to ISO 17025 standards in Questioned Document Examinations and Handwriting.

Commendations

- Commended by the Serious and Organised Crime Agency (SOCA).
- Melanie undertakes confidential work within the UK's Home Office, including internal investigations and counter-terrorism.

Expert Witness

Melanie has worked on many high-profile cases, including murders, kidnappings, rapes, counter-terrorism, serious fraud, money laundering, drugs, organised crime, witness intimidation and civil litigation.

She also specialises in civil litigation casework involving signature authenticity. Melanie provides evidence to Courts and Tribunals on a regular basis, acts as a Court appointed Single Joint Expert and is familiar with the Civil Procedure Rules.

As part of her duties Melanie is available to work on a pro-bono basis, providing her professional services to those that need it.

ANNEX B**List of Main Tests and Techniques****Explosive Substances:**

- Spots tests (including the Greiss Test)
- Burn Tests
- Fourier Transform Infrared Spectroscopy (FTIR)
- High Performance Liquid Chromatography – Electrochemical Detection (HPLC/ECD)
- Ion Chromatography
- Gas Chromatography – Flame Ionisation Detection (GC/FID)
- Gas Chromatography – Thermal Energy Analysis (GC/TEA)

Explosive Devices:**Fingerprints:**

- Powdering (and lifting)
- Chemical enhancement
- Photography
- Fingerprint Identification
- Use of databases

DNA:

- Finding DNA
- DNA profiling process
- Second Generation Multimix (SGM)
- Use of databases
- [Low Copy Number (LCN)]

Textile Fibres:

- Finding textile fibres
- Low Power Microscopy (LPM) – transmitted light
- Polarising Light Microscopy (PLM)
- Comparison Microscopy – transmitted light
- Microspectrophotometry (MSP)
- Thin-Layer Chromatography (TLC)
- High Performance Liquid Chromatography (HPLC)
- Fourier Transform Infrared Spectroscopy (FTIR)
- Linking Fibres

Marks and Traces:

- Finding traces
- Low Power Microscopy – incident light
- Comparison Microscopy – incident light
- Glass Refractive Index Measuring system (GRIM)
- Scanning Electron Microscope (SEM)
- Interference Microscopy, and Blue/UV Light Microscopy
- Fourier Transform Infrared Spectroscopy (FTIR)
- Pyrolysis Gas Chromatography/Mass Spectrometry (GS/MS)

Questioned Documents:

- Handwriting comparisons
- Electrostatic Detection Apparatus (ESDA)
- Light-based imaging using UV and IR light
- Photographic and Video Spectral Comparators (VSC)
- Thin-Layer Chromatography (TLC)