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Fire and Explosives Investigation 2015
Challenges and Opportunities

Forensic Science Special Interest Group
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Fires and Explosives Investigation: Challenges and Opportunities

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Contents

Introduction

The Forensic Science Special Interest Group (SIG) has produced this report to provide a resource to the forensic community; identifying the challenges and opportunities within the field of fire and explosives investigation.

To produce this report we brought together the fire and explosives community in a day-long workshop, comprising of presentations from a range of speakers, followed by discussion sessions directed by the challenges identified by the speakers and taken from the SIG's "Forensic Science UK Innovation Database".[1] The results of these discussions have been compiled into this report.

Report structure

When reviewing the outcomes of the discussions it became clear that there were several broad themes that applied to fire, explosives and explosion investigation. These are covered first, followed by some specific challenges discussed during the workshop.

Speakers:

DR MATTHEW BEARDAH
Group Principal (Capability), Forensic Explosives Laboratory *Forensic Explosives Investigation: Headline R&D Challenges*

DAVID BRYSON
University of Derby *The Challenge of Fire Scene Photography: Is High Dynamic Range Imaging a solution?*

STEVE JOHNSON
Cranfield Forensic Institute *Triaging the tide: Balancing intelligence and evidence*

PROFESSOR NIAMH NIC DAEID
Centre for Anatomy and Human Identification, University of Dundee *Challenges in Fire Scene Investigation*

MARTIN SHIPP
Technical Development Director, Fire Safety, BRE Global (Building Research Establishment) *Fire Investigation by BRE*

1 https://connect.innovateuk.org/web/forensics/databases

Background

A knowledge of the current landscape is vital to allow the field to move forward. The UK has a reputation as one of the world leaders in forensic science, however with the development of DNA fingerprinting by Sir Alec Jeffreys in the 1980s being recognised as the last major UK contribution to forensic science many leading practitioners and academics believe that this standing is in jeopardy.[2] [3] [4]

Government statistics for England show that in the period 2013-14 fire and rescue authorities attended 170,000 fire incidents, of which 46% were deliberate fires. There were 275 fire fatalities and 3,614 non-fatal fire casualties as a result of these recorded fire incidents.[5] In addition to the human cost of fire incidents, there is also a significant financial aspect (in 2008 this figure was estimated at £8.3bn for England alone).[6] The fire investigation field is complex with a small number of forensic service providers (FSPs) providing fire investigation meaning that a portion the work is done by trained investigators within the fire and rescue services. There is also a combination of public and private sectors involved in fire investigation. With the high human and financial cost of fire incidents there is pressure on investigators to ensure that, in the case of deliberate fires, those responsible are brought to justice and with accidental fires that safety lessons are learnt and appropriate compensation awarded.

At the time of writing (June 2015) the UK threat level from international terrorism is assessed as severe (on a scale of low, moderate, substantial, severe and critical), this means that an attack is "highly likely".[7] While not all acts of terrorism involve explosives, many attacks do involve explosive devices. Attacks using explosive devices can cause substantial loss of life and damage to infrastructure. While a large focus is understandably on preventing attacks using explosive devices, consideration also needs to be taken for post-blast investigation. This creates a complex landscape with many overlapping technologies. Terrorism is a global issue and therefore the investigation of explosions cannot be treated as solely a UK concern. The evolving nature of the explosive threat, as the bomb makers adapt to circumvent existing detection technologies, means that new methods, technologies and ideas are constantly needed by investigators.

There are several similarities between fire investigation and post-blast investigation. Both types of scene are dangerous and complex with lots of debris, and in both cases, investigators will often be searching for minute traces of evidence. Both types of scene are often further complicated by the involvement of emergency services and a pressure to process the scene as swiftly as possible. The first priority is, quite rightly, the preservation of life and treatment of casualties at a scene. However, there is also a need to preserve the evidence as much as possible to allow a thorough investigation an maximise the chances of catching the perpetrators. This means that emergency services and investigators must work together to ensure the best possible outcomes.

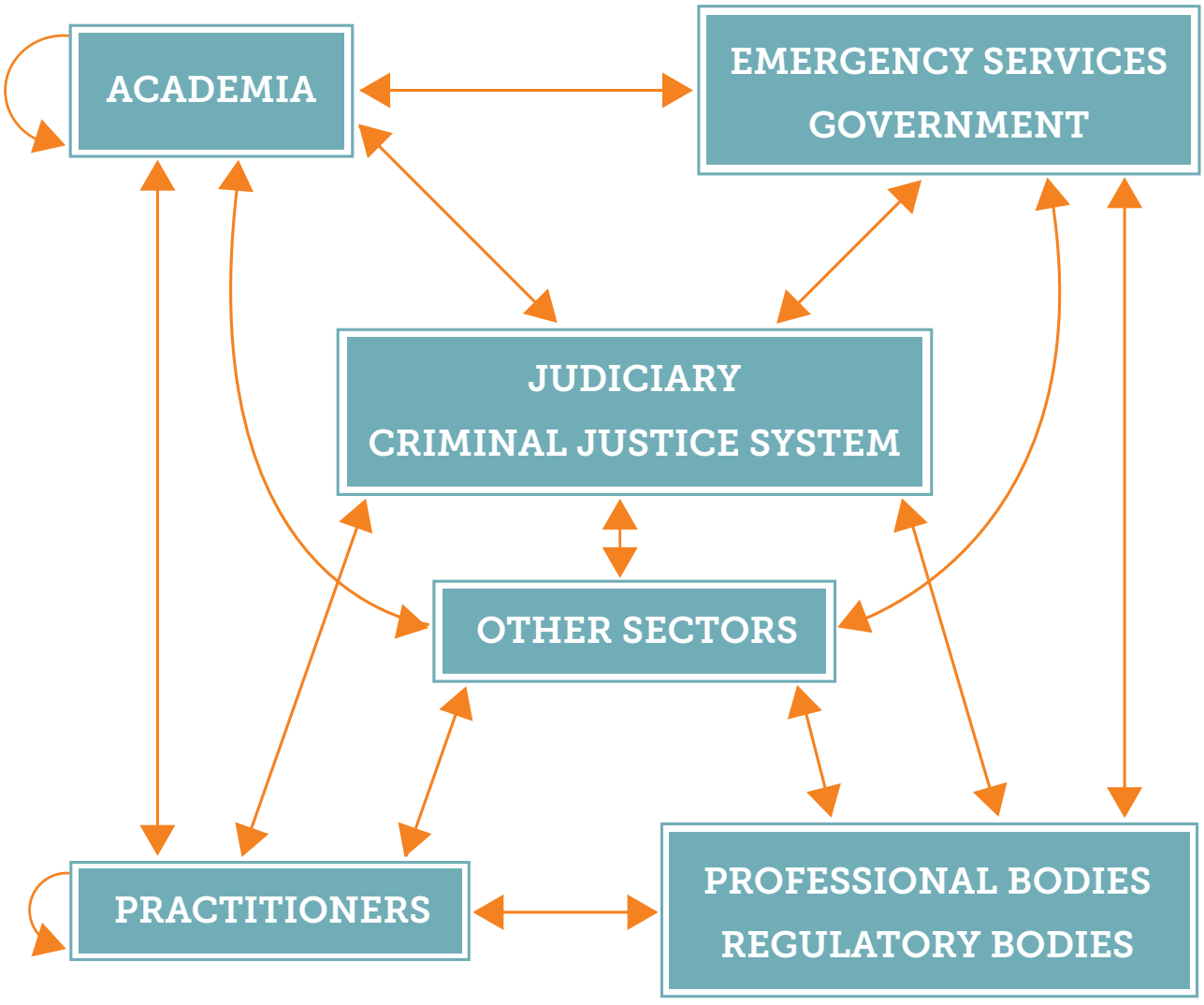
The UK and world landscapes are complex. This can be challenging but also provides innovators with opportunities to move forensic science in this area forwards. To fully exploit these opportunities a good knowledge of the challenges is required to help direct research and innovation.

2 http://www.bbc.co.uk/mediacentre/proginfo/2015/16/forensics-in-crisis
3 http://rstb.royalsocietypublishing.org/content/370/1674
4 https://royalsociety.org/events/2015/02/forensic-science/
5 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/325696/Fire_Statistics_Monitor_April_2013_to_March_2014_final__3_.pdf
6 http://webarchive.nationalarchives.gov.uk/20121108165934/http://www.communities.gov.uk/documents/corporate/pdf/1838338.pdf
7 https://www.mi5.gov.uk/home/the-threats/terrorism/threat-levels.html

Communication and Knowledge Transfer

A recurring theme across the fields of fire and explosives investigation is that of communication. There is a need for efficient communication both within each field and in the wider community. Effective communication is key to ensuring that key knowledge is transferred and progress can be made.

The lines of Communication needed between key areas



Key communication areas:

1. Within academia

The UK has multiple universities conducting forensic research, however a lack of communication between institutions can result in repetition of work. Encouraging increased communication and collaboration between universities would increase the output of novel research. However, the competitive nature of academic research must be taken into account and collaborations that are forced are unlikely to yield productive results. The Forensic Science UK Innovation Database could help to prevent repetition of work through researchers identifying in the comments section that they are engaging in research in a particular challenge.

Another factor in ensuring that research is not repeated is to publish information on research into techniques that did not succeed. An example within the fields of fire and explosives investigation would be research into extraction methodologies. Due to the complex and varied nature of the matrices that you want to extract evidence from there are multiple methods that could be applied to any specific situation. If only successful methodologies are published there is a risk of repetition of techniques that failed, but were not reported. A solution to this might be a centralised resource where researchers could input both successful and unsuccessful methodologies. This could also provide as useful resource for practitioners.

2. Academia and practitioners

The results of academic research does not always reach practitioners. This creates a situation where there is a risk of research being repeated and opportunities to improve the forensic capabilities of the UK are being missed or delayed. Therefore, there is a need for clear channels of communication between academia and practitioners, who may not have sufficient time to read journals. The Forensic Science SIG can act as a conduit for increased communication.

Another aspect of the lack of communication between academia and practitioners is often the lack of contacts within relevant practitioner communities. This can result in research projects being unable to be taken forward due to a lack of field trials. This runs the risk of novel research not reaching fruition as a finished product. Once again the SIG can act as a conduit for increased communication, bringing together academics and practitioners to help facilitate field trials and other testing. However, this is reliant on both practitioners and industry being prepared to interact with the SIG to allow for connections to develop.

Communication between academia and practitioners needs to move both ways. Whilst academics need to communicate their research, practitioners need to communicate their needs. Without the practitioner needs being known, academic research is undirected and this can result in research that doesn't lead to an end product that aids the community. Therefore, practitioner input from an early stage is vital to define a specific need and to direct research towards an end product. The Forensic Science SIG has been active in this area, looking for ways to help target research. The result has been the production of the Forensic Science UK Innovation Database,[8] which can be used as a resource for academics to identify specific research projects that have been identified by practitioners and others involved in the field. However, this requires academics to follow up with the contributor of a specific challenge to obtain more information on the requirements. It also requires practitioners to continue to provide relevant challenges to the Database.

The communication of practitioner needs must be clear not just in terms of the research problem but in the definition of a successful outcome. For example, it is unlikely that a new methodology that can give a moderate increase in sensitivity, but costs twice as much as the existing technique, would be suitable for routine use.

3. To other stakeholders

When there has been a fire or explosion there are other parties involved, such as the police and fire service, as well as government and international bodies. It is important that all stakeholders are effectively communicated with. This communication should extend from discussion of procedures prior to any potential event through to and findings and lessons to be taken away following a full investigation. Communication between these groups must not simply be limited to during an

8 https://connect.innovateuk.org/forensics/databases

incident, otherwise information that could prevent incidents being repeated may be missed.

It is particularly significant in the case of accidental fires or explosions that the findings of the subsequent investigations are widely disseminated so that changes to policy and materials can be made. Further to this, where research is carried out to assess potential new risks, this information needs to be disseminated. For example, some potential emerging fire risks that have been identified by BRE are:

- Highly-insulated buildings – insulating materials can be flammable. With a focus on making buildings more energy efficient, by preventing heat loss, it is expected that there may be an increase in insulation materials.
- Accommodation in sheds and garages – there is a growing trend in areas where accommodation is at a premium for garages and sheds to be adapted for accommodation that can then be rented. Many of these adaptations are not carried out to a high standard and can increase the risk of fires.
- Hoarding – situations where individuals hoard materials can pose a fire risk, particularly when the hoarded materials are highly flammable, such as newspapers. Hoarding also poses a challenge to fire fighters as the scene may be difficult to move through due to clutter.
- Mobility scooters – there is an increased use of mobility scooters, and their maintenance and storage can present fire risks. For example the charging of such electric devices can increase the risk of electrical fires and improper storage can also lead to a risk of the scooter blocking exit routes from a building.
- Photovoltaics and other renewable energy technologies – as new technologies are developed there is a need to ensure that they do not pose a fire risk and that any risks can be minimised.
- CE marking – there are updated requirements on the materials that need to be CE marked, work is required to ensure that materials are correctly marked and that materials that do not reach the required standard are not marked. This will help to prevent sub-standard materials being used as such cases can lead to fires.
- Recycling depots – as an increased number of goods can be recycled it is necessary to understand the risks that these materials pose and how they can be recycled safely
- Lithium-ion batteries – these batteries are becoming increasingly commonplace and can be found in digital cameras and other portable electronics. While research on the risks of these batteries has been conducted in the past there is scope for further research looking at the risks associated with their more mainstream uses that result in them being found in most homes in the country.

However, the challenge is how to disseminate the findings to the relevant stakeholder groups. There appears to have been a fragmentation of the field with multiple membership bodies. This makes it difficult to know the most effective way to reach the target audience. Further to this is the question of the most effective way to present the information. It is likely that the method of dissemination depends upon the nature of the information and the target audience. Possible methods of dissemination include:

- Via stakeholder organisations themselves
- Journal articles and research reports
- Inquiry and Coroner's reports
- Conferences, seminars and continuing professional development (CPD) events
- Standards and guidance
- Web-based knowledge exchange services, webinars and e-newsletters

Whichever method of dissemination is selected, it must ensure that the information reaches the right people in a timely and effective manner.

Communication with the police and fire service is vital to ensure that the maximum amount of information can be retrieved from a scene while ensuring that risk to those involved with processing the scene are minimised, and that there can be a safe evacuation of those injured at the scene. The expectations of the police must be managed in relation to the extent of the capabilities of forensic science as while the "CSI effect" is mainly referred to in relation to the public's perception of forensic science it can equally affect the police.[9]

9 The "CSI effect" is the term used to describe the effect of television shows such as CSI and Silent Witness on the public perception of forensic science. While many shows such as these have scientific advisors, artistic license is employed and significantly the timeframe of an investigation is drastically shortened and virtually always the case is fully resolved. This can distort the perception of those who watch the shows to believe that forensic science is quick, state of the art and can always provide all the answers, which unfortunately in reality is not the case.

4. To the judiciary and others in the criminal justice system

There is a need for clear and accurate communication with members of the judiciary. This is vital because ultimately it is the judiciary who make the decision as to what forensic evidence is admissible in a court room. Therefore, new technology and techniques must be clearly explained and the limitations clarified.

In addition to members of the judiciary, all those working in the criminal justice system should have access to relevant information on the forensic techniques available and their limitations. As with members of the police forces, it is possible for lawyers to be affected by the "CSI effect".

5. Communication to other sectors

There is a risk that the fields of fire and explosives investigation and forensic science as a whole can be too insular. This results in missed opportunities to incorporate innovation from other sectors into the field.

An example of where good communication can result in improvements is the use of food bags to package evidence from fire scenes. Packaging of evidence is an area of fire investigation that, in many countries, requires improvement. In the UK, nylon bags are used but they are not robust and can leak vapours. In other parts of Europe glass jars are used, these can work well but they are fragile. In the USA tin cans are used, these have the problem that they lack a chemical lining that can result in issues with rust if evidence is stored for a longer period. In Scandinavian countries they have adopted the use of food bags. These work well and provide an example of cross sector interaction. However, while this is a positive result, as a solitary example it highlights that other regions have not reached out to other sectors. In addition, it highlights a further lack of communication as other regions have not looked to take advantage of the development.

6. Communication among professional bodies

Due to the fragmentation of forensic science, the UK is in a position where there are a multitude of different professional bodies. Many of these bodies have a role in setting standards. However, there needs to be communication amongst these bodies to ensure that work isn't repeated and that standards are truly standardised. A key role in this within the UK is that of the Forensic Science Regulator. The Regulator 'ensures that the provision of forensic science services across the criminal justice system is subject to an appropriate regime of scientific quality standards.'[10] Therefore when developing any standards for the UK the Regulator should be the first port of call.

10 https://www.gov.uk/government/organisations/forensic-science-regulator/about

Education

Education of the next generation of forensic scientists is vital to ensure the continuation of the provision of forensic science within the UK. Since the closure of the FSS, the forensic field has lost one of its core mentoring processes. This is an issue across the whole forensic field, but fires and explosives investigation has some additional challenges.

Hands on experience

It is vital for students to gain hands on experience. This is one of the reasons why many University courses now include simulated crime scenes for students to investigate. However, due to the nature of the site of a fire or explosion this can be harder to replicate than other areas of forensic science, without resulting in the same risks (and health and safety issues) that would occur at a real scene. Similarly, investigation companies ideally want to let new practitioners, placement students and apprentices experience real scenes but this is not always possible.

Due to their dangerous nature, it can be difficult to study and to research the progression of fires and explosions. This is where specialist facilities can aid in the training of others. An example of this is the Cranfield Forensic Institute, which has the necessary facilities and licensing for the handling of explosives and, therefore, is well placed to offer training in this field.

Are apprenticeships the way forward?

One way to bridge the gap left by the closure of the FSS and its mentoring process would be for companies to take on apprentices, although in the current period of austerity the associated cost may be a significant disincentive.

However, an apprentice may be favourable compared to the costs of employing those with higher academic qualifications and they are often seen as too expensive; preventing young scientists from coming into the industry and could, in the long-term, force forensic science graduates to find jobs outside the sector, resulting in a lack of skilled forensic practitioners.

Training and CPD

It is vitally important that forensic practitioners have proper training at the start of their careers and that this is followed up with continuing development. A vital part of the initial training is to dispel some of the myths surrounding forensic science. Training can take place at universities or within companies, however it is important that the training is of a suitable standard.

Continuing professional development (CPD) is vital to ensure that practitioners maintain and further develop their skills. This is also an opportunity for new developments to be disseminated. Many companies have their own CPD programs, however the Chartered Society of Forensic Science also offers CPD courses and provide certification of the particular skills needed for practitioners in the fields of fire and explosives investigation through their Diploma. This is significant for independent practitioners as it provides an opportunity to have their competencies assessed and recognised.

It is important that there is standardisation and assessment of skills to ensure that regardless of the background of the practitioner the work they carry out is of an acceptable standard for the courts.

Educating the public

The popularity of shows such as CSI and Silent Witness has resulted in a greater public awareness of forensic science, however it has also led to unrealistic expectations in terms of capabilities. Improving the public's understanding of the science should result in greater acceptance of new techniques and for juries to have realistic expectations of the capabilities of forensic science.

Funding

With the UK in a period of austerity, funding for research has been being squeezed across all disciplines, and there is an impression that in order to obtain funding, a research project needs to feature 'sexy science', meaning that more mundane but equally necessary projects such as persistence studies may get passed over.

Cuts to available funding can result in a reduction in amount of research carried out. However, this austerity could be taken as a stimulus for collaboration. It can focus innovation to the areas that most need them. However this relies upon good judgement on the part of those allocating funding, and the ability of those applying for funding to accurately convey the importance of their research. A lack of funding can also force researchers to be more innovative in ways of securing money and could increase the chances of collaborations with organisations outside the forensic sphere.

It is crucial that those involved in R&D in this area adapt to the restrictions placed on funding so that this important work can continue.

Specific challenges

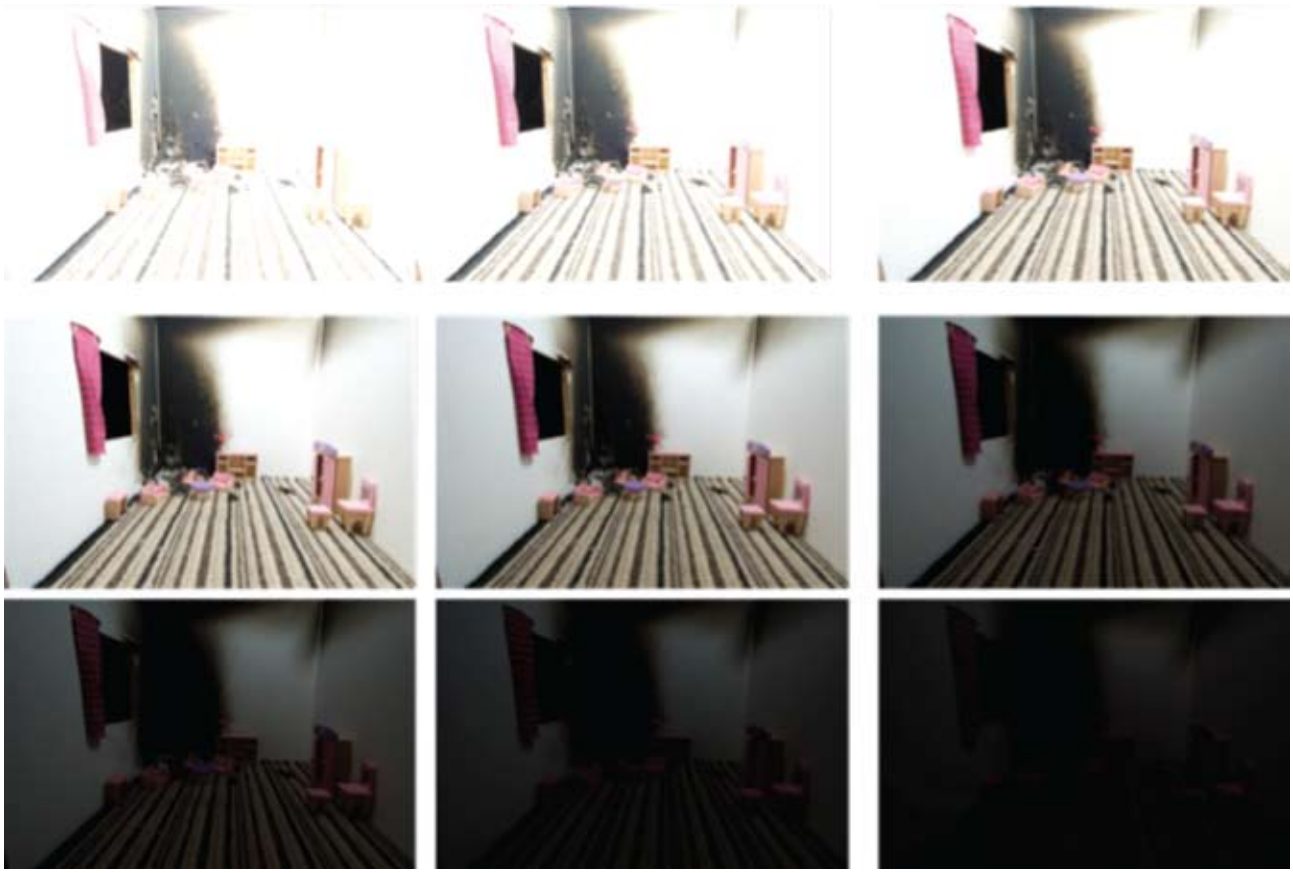
1. Imaging and recording the scene

Both fire and explosion scenes are challenging environments. In addition to the hazardous elements of the site, there may also be time pressures to clear the area. Therefore, there is a need for improved techniques for safely, accurately and quickly recording the scene.

Imaging and recording the scene is an area where there are many opportunities to incorporate modern technologies. For example using tablet computers such as iPads to record notes and cloud based systems to upload information directly to laboratories and control rooms. Cameras and imaging technology has also come forward with the advent of digital cameras and high definition imaging.

Using imaging to accurately capture the crime scene means that it is possible to revisit the scene in a virtual setting at a later date when visiting the physical location is no longer possible. Imaging techniques may also be able to identify evidence not immediately visible or obvious to the naked eye.

One potential technique for capturing the scene is high dynamic range imaging. The concept of this technique is that rather than capturing a single image, a range of images capture everything from the shadow detail all the way through to the highlight detail. The original RAW files are kept untouched and the process can be automated through software. Research into this technique has demonstrated that it has potential, but the next step is to employ it at mock and real fire scenes. This requires the co-operation of those who would trial the technology and comes back to the previously raised issue of communication.



Examples of images taken across the range of exposures

The resulting HDR image

This is not the only new technology that could be applied to this challenge. Other suggestions include combining UV and IR technology to conventional photography and recording. As well as improving the photographic technology, adapting it to make its use easier is another way to improve scene recording. One way to do this is to take the camera out of the CSI's hands, freeing them up for other tasks or simply giving them better balance when moving through a scene. In the Netherlands, at the Netherlands Forensic Institute's CSI The Hague, they have developed a headset camera and similar work is being investigated by the Security Innovation and Demonstration Centre (SIDC) here in the UK. Once again, this demonstrates an importance to communicate through the forensic community to prevent work being repeated.

The use of drones and robots to image scenes has also been put forward as a potential improvement to scene recording. However, these may not be suitable in fire and explosion scenes due to various hazards and obstacles that may be present. The cost of such equipment might also be a prohibitive factor.

2. Extraction methodologies

The extraction of samples from fire and explosives debris is very similar, with both scene types producing complex matrices for extraction. When attempting to extract and identify explosive or ignitable liquid residues, there are a variety of concerns to be addressed. These include whether the particular sample also needs to be examined for DNA and other evidence types, as extraction techniques for explosive and in particular ignitable liquid residues can involve heating the sample, which could have a negative effect on any DNA present. If other evidence types must be taken into consideration, which takes priority, or is it possible to ensure that all evidence types can be recovered by carrying out examinations in such an order so as not to disturb or destroy anything?

When the focus is solely on the extraction of ignitable liquids or explosive residues and their analysis, the most frequently used technique is headspace extraction followed by GCMS (gas chromatography mass spectrometry) analysis. However, depending on the material you are searching for, this may not always be the most appropriate technique as not all materials extract well using headspace techniques and some chemicals do not separate well using GCMS. Other techniques that can be applied to this area include ion chromatography for explosive residues and GC-FID (gas chromatography flame ionisation detection) for ignitable liquids. In addition to identifying alternative methods, there is also scope to optimise existing methods. This optimisation might be in the form of reducing the time taken for analysis, requiring a smaller amount of sample for analysis, increasing the number of compounds detectable with that analysis, reducing the cost or increasing the safety of the analysis (e.g. replacing harmful extraction solvents with safer ones).

Any new or altered methodologies must be validated and there are certainly benefits to having universal methods. It is also necessary to consider whether the risk and financial investment required to implement a new technology are worth the improvements that it offers. This is where it is vital that there is good communication between researchers and end users. By starting communication before any research has taken place; that research can then be directed to ensure that, when a new methodology is developed, it will meet the end-user requirements and have a greater chance of being pulled through into use by service providers. This is an area in which the SIG can help, with the Innovation Database detailing specific research challenges and providing contacts to end users for discussions prior to starting any projects.

Communication is also important is in detailing research that has already been carried out. Regarding extraction methodologies, it is common for successful new techniques to be published but limited information provided on those that failed. In many ways, this information would be more useful to other researchers as it would prevent constant repetition of research into methodologies that do not work. One suggestion to help overcome this would be the introduction of a database of methodologies. This would pull together all the know extraction techniques both successful and unsuccessful into a centralised resource. However, this would require funding to implement and decisions would need to be made as to who had access and could upload information to it.

The merits of extraction in situ versus in the lab were also discussed. While current analytical techniques are not sufficiently robust to be carried out in situ, there is limited value in carrying out extraction in the field. However, as the technology improves, the ability to

conduct extraction and analysis away from the lab is the long-term goal.

The analysis of extracted materials should be flexible, as long as the ability to go back to the raw data, if further questions are asked, is retained without the need for re-sampling. An example of this in a different field is the way that sample results are kept from doping tests in sport. Samples taken during the 2012 Olympics have been analysed in such a flexible manner that they can be re-reviewed as new intelligence becomes available.

3. Are databases useful?

The specific example of a database discussed was the production of a chromatographic database of ignitable liquids and pyrolysis products. Such a database would be a central resource containing chromatograms of ignitable liquids and pyrolysis products.

In order to produce such a database, a large amount of information would need to be collected, collated and stored. This incurs costs, both in order to set up the database and to ensure that it is maintained and updated regularly. As any resource is only as good as the information within it, there would need to be regulation on the information that could be placed in the database. This could be through ensuring that those who submit any new data have first produced a chromatogram of a known standard to demonstrate that the instrumentation is working correctly. Those submitting could also have to follow a set method. These controls might allow for a situation where anyone who fulfilled the conditions could upload data rather than the organisation hosting the database having to process any new data.

The exact nature of the data submitted would also need to be defined so that the database did not become overwhelmed with extraneous data. This could be achieved by ensuring that the purpose of the database was well defined. Similarly the design of the database should be such that it is was simple to locate the information that an individual was searching for as there is no point creating a repository of information that is not user friendly so eventually people stop using it.

The question of access is also a key issue when discussing the implementation of a centralised database. In an ideal world, any such database would be accessible to anyone. However, with increased concern about intellectual property and commercial confidentiality regarding the composition of materials that might have chromatograms within the database, this might not be possible. Therefore, decisions must be made as to who has access and how this access is controlled.

It is also possible that a database of this sort is not necessary. Most forensic laboratories have their own in-house databases that are linked to a particular instrument. While inter-instrument variation would be eliminated as much as possible, with controls such as running standards and using standardised methods, some practitioners might feel more trusting of their own in house database rather than a database that would have been produced on a variety of different instruments. Therefore there is a school of thought that suggests that the money that would be used on a centralised database would be better-used ensuring standardisation of the types of databases and matching algorithms used by individual laboratories.

Ignitable liquids and pyrolysis products are not the only materials that could benefit from a centralised database, however the questions remain when setting up any database; who is going to manage it, who is going to supply the data, who is going to use it, and who is going to pay for it.

Summary and next steps

The workshop highlighted three recurring themes within the fields of explosives and fire investigation; communication and knowledge transfer, education and funding. The challenges in these areas are not exclusive to these fields and are issues that need to be addressed across the forensic science arena.

The workshop demonstrated through discussion of specific challenges such as how best to image the scene of a fire or explosion that there are research opportunities in this field. However, tying into the main themes, the needs of the end user community need to be effectively conveyed to the researchers, and there should be a focus on collaboration to help maximise the opportunities for funding.

There is an opportunity for the Forensic Science Special Interest Group to aid the community across the main themes, in particular regarding communication and knowledge transfer where the SIG can act as a central contact point and help to put end users in contact with researchers and vice versa.

Looking to the future there is much that can be done to improve the current situation in fire and explosives investigation. The Forensic Science Special Interest Group is ideally placed to co-ordinate such efforts, however this will require co-operation from the multitude of organisations that are involved in this area.

This report should be a starting point to spark further discussion and it is key to get the wider community involved. This could be achieved in several ways, including a series of workshops around the country and online consultations. It would also be important to engage with organisations within Europe and further afield as one of the current issues highlighted was that the UK community has become too insular.

There are significant opportunities for innovation within the field with the workshop only featuring some of the headline challenges. The SIG can play a role in gathering the opportunities for innovation and bringing together researchers and end users to work on these opportunities. The SIG can also look to collate the results of existing research and document on-going work to help prevent repetition.

The interest in the workshop demonstrates that there is an awareness amongst the community that there is much work to be done to ensure that the UK remains a leader in the field. The acknowledgement that there are issues and an enthusiasm to be part of the solution are important first steps to tackling the problems. However, it will take an on-going commitment to change and a focus on innovation to translate this enthusiasm into results. The SIG can be a driving force in this area, with the support of the community.