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Forensic Science in the 21st Century Will Trace Evidence Ever Reach the Next Level?

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2- Australian Federal Police, Canberra, Australia
3- NSW Police Service, Australia
4- University of Canberra

Presented at the Trace Evidence Symposium, Clearwater Beach FL, 13-16 August 2007

Hollywood Myth

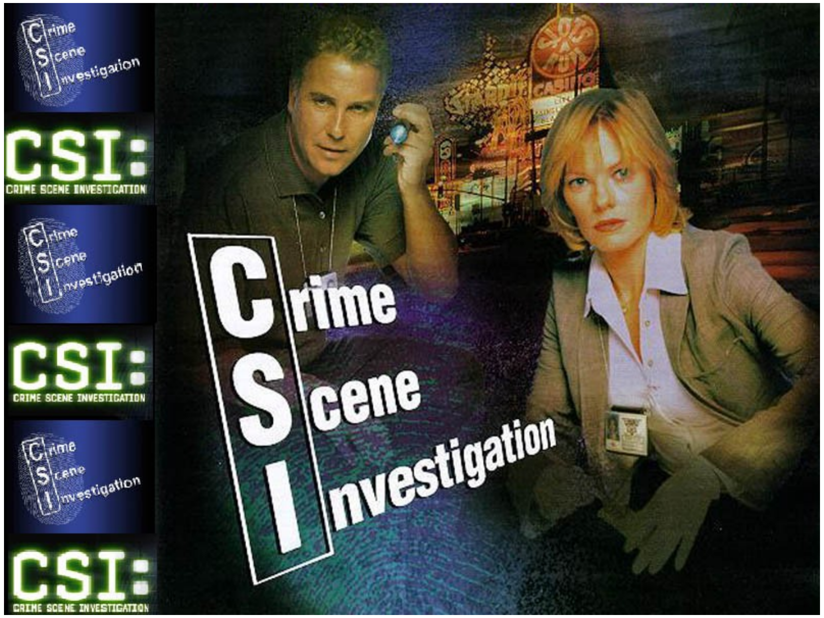
THE RESOURCES ARE INFINITE

EVERYTHING CAN BE ANALYSED QUICKLY

THERE IS NO UNCERTAINTY

THE OFFENDER IS ALWAYS IN THE DATABASE!

Etc, etc.



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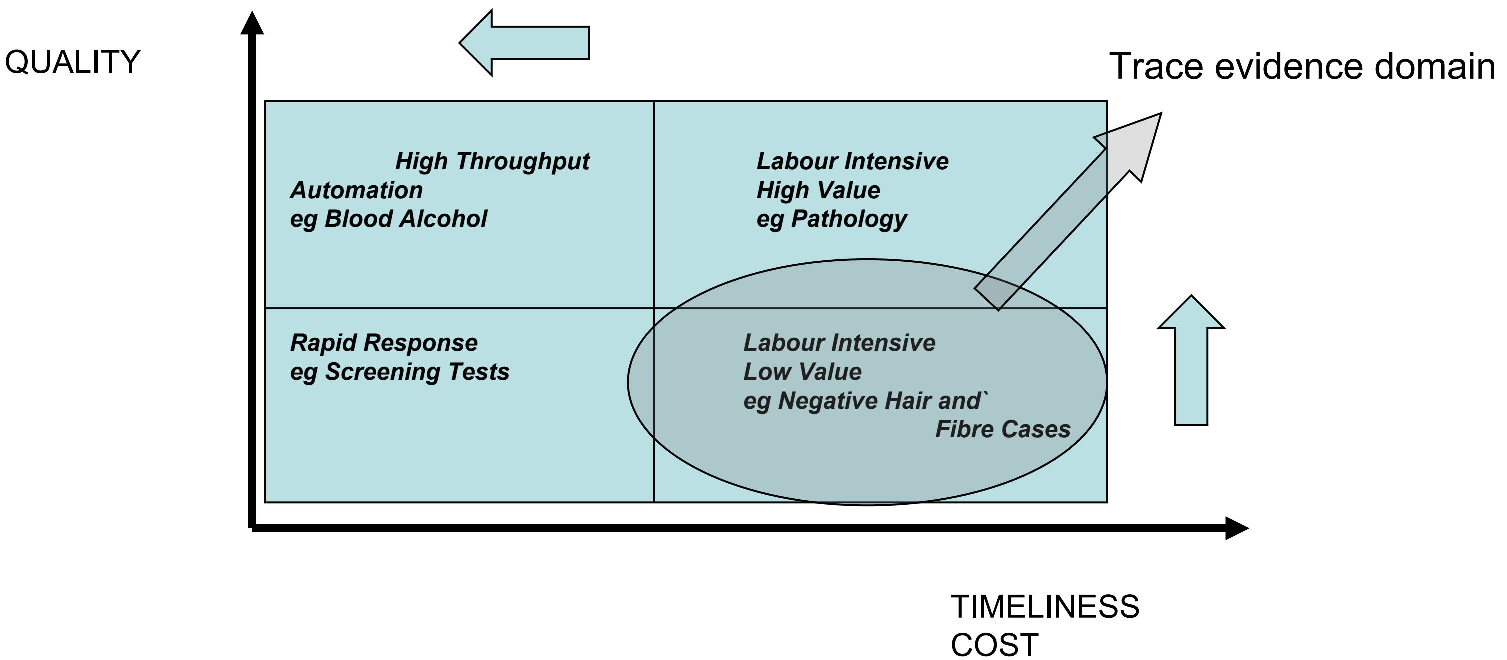
QUALITY, TIMELINESS AND COST



Adapted from Kobus H., An Analytical Science Based Approach to the Identification Forensic Sciences, 18th International Symposium on the Forensic Sciences (ANZFSS Symposium), 2-7 April 2006, Fremantle, Australia.

Improving the Value of Trace Evidence

— Makes significant progress to address the 'could have come from' syndrome:

- Being more informative and more accurate in the conclusion would undoubtedly improve the value of trace evidence.
- Glass pioneered this field for Trace Evidence.
- Efforts in designing research to produce relevant and reliable statistical data should be significantly expanded to most, if not all, types of trace evidence.

Let's be serious about it!

Cartoon: http://www.westwiltshire.gov.uk/Bins/fraud/p10.htm *"posterior"* *"prior"*

Pr(Guilt|Evidence) = Pr(Guilt) x Likelihood Ratio

$$\frac{p \quad E \mid C}{p \quad E \mid C}$$

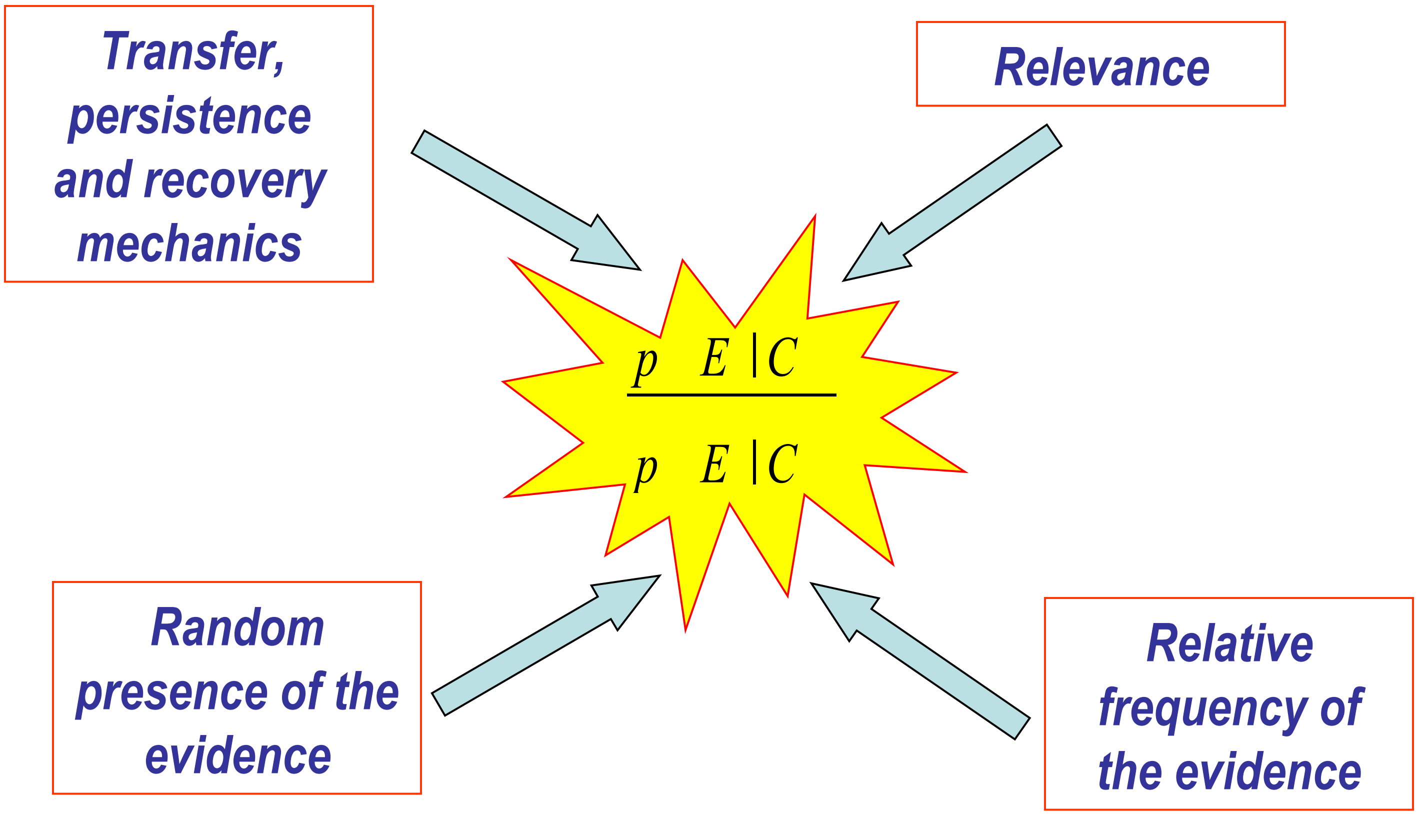
Which values can we use?

One Major Criticism

— We do not have values to apply in the Bayesian framework

— Hence this approach is useless

Throwing the baby out with the bathwater



Champod C. & Taroni F., (1999) The Bayesian Approach. In Forensic Examination of Fibres 2nd ed., Robertson J. & Grieve M. (Eds), Taylor & Francis, London, 379-398

Changing Face of Forensic Science

— Forensic Science **MUST** be more:

- Proactive
- Predictive
- Intelligence based

— Close to real-time response

Photos: AFP

Trace Evidence and Forensic Intelligence

— Trace Evidence plays a crucial role in an investigative/intelligence framework, because it can:

- Give investigative leads in the absence of comparative material
- Assist in reconstructing the scene or a series of events
- Identifying links between different cases
- Assist in systematically analysing large scale criminal phenomena.

— This application of forensic science data is still under-exploited. When this potential is fully realised, the value of trace evidence will also be upgraded because it can be seen as a crucial source of information.

The Dilemma

— Results with 99.9% accuracy which takes 6 months (or more), or

— Results with, say 80% accuracy, but close to real time

????????

— Is the trade-off compatible with the high demand and scrutiny from the Justice System?

Common Problems

— Most forensic testing is done in the laboratory

— The equipment tends to be large and expensive

— A large amount of laboratory space is required

— It takes time to transport samples to the laboratory

— It takes time to process each sample and produce a result

— Most laboratories work with significant backlogs; so

— Often the analytical results are not available until the police investigation is nearly (or is already) completed

Luckily, thanks to modern technology, putting yourself out of your misery has never been more convenient or affordable.

Technology

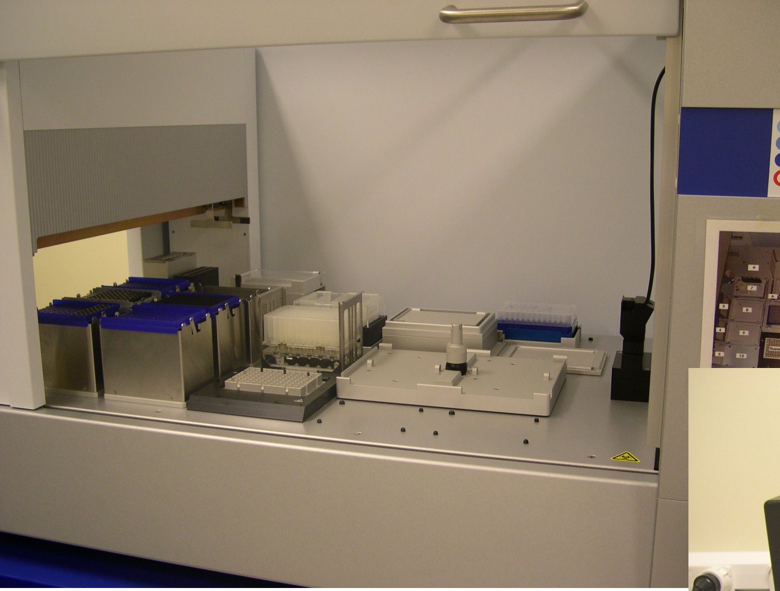
≠

Science

Keys to avoid 'gadgetry':

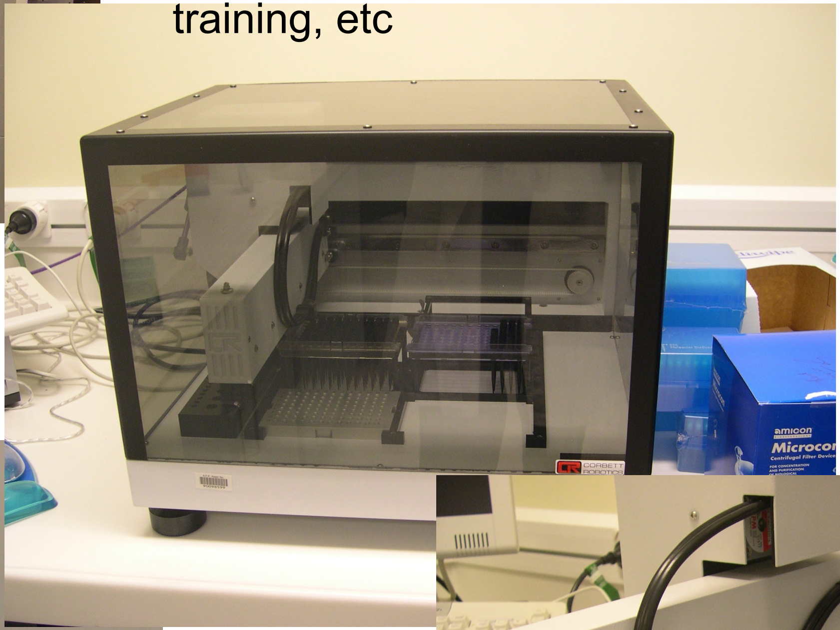
Technology must be fit for purpose

Criminalistics should never be out of sight

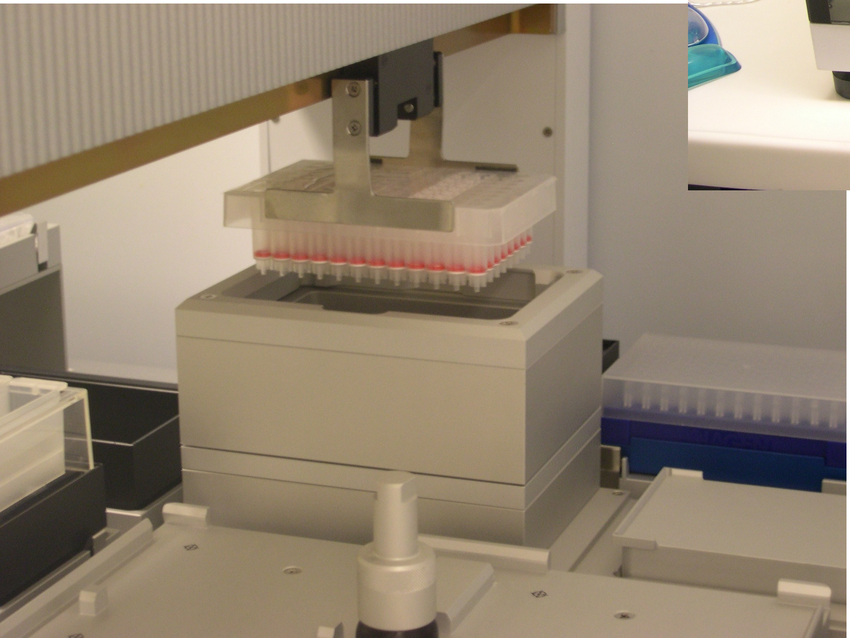


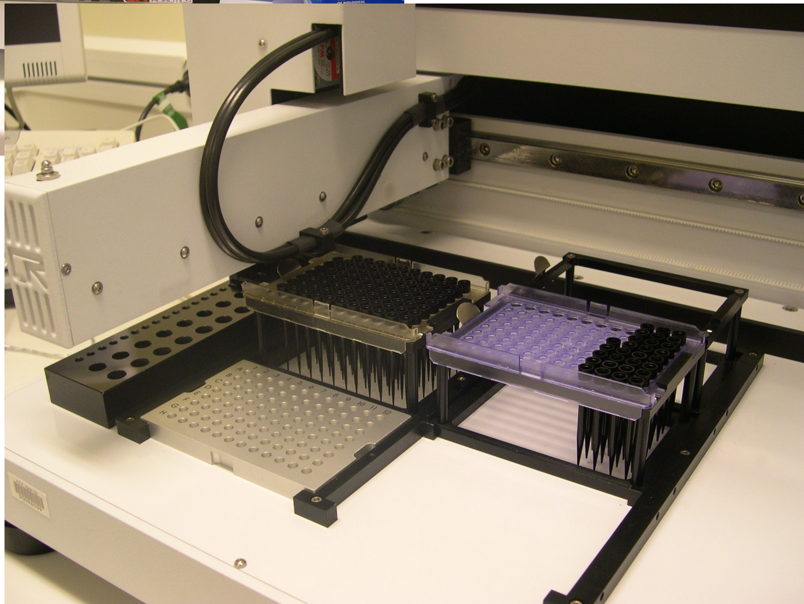
Automation – eg. DNA Robotics

- Increased throughput
- Reduced chance of error
- Improved sensitivity
- Personal can spend more time on front end analysis, training, etc



Photos: Dr Paul Roffey, AFP





Examples of new technologies applicable to trace evidence/chemical criminalistics

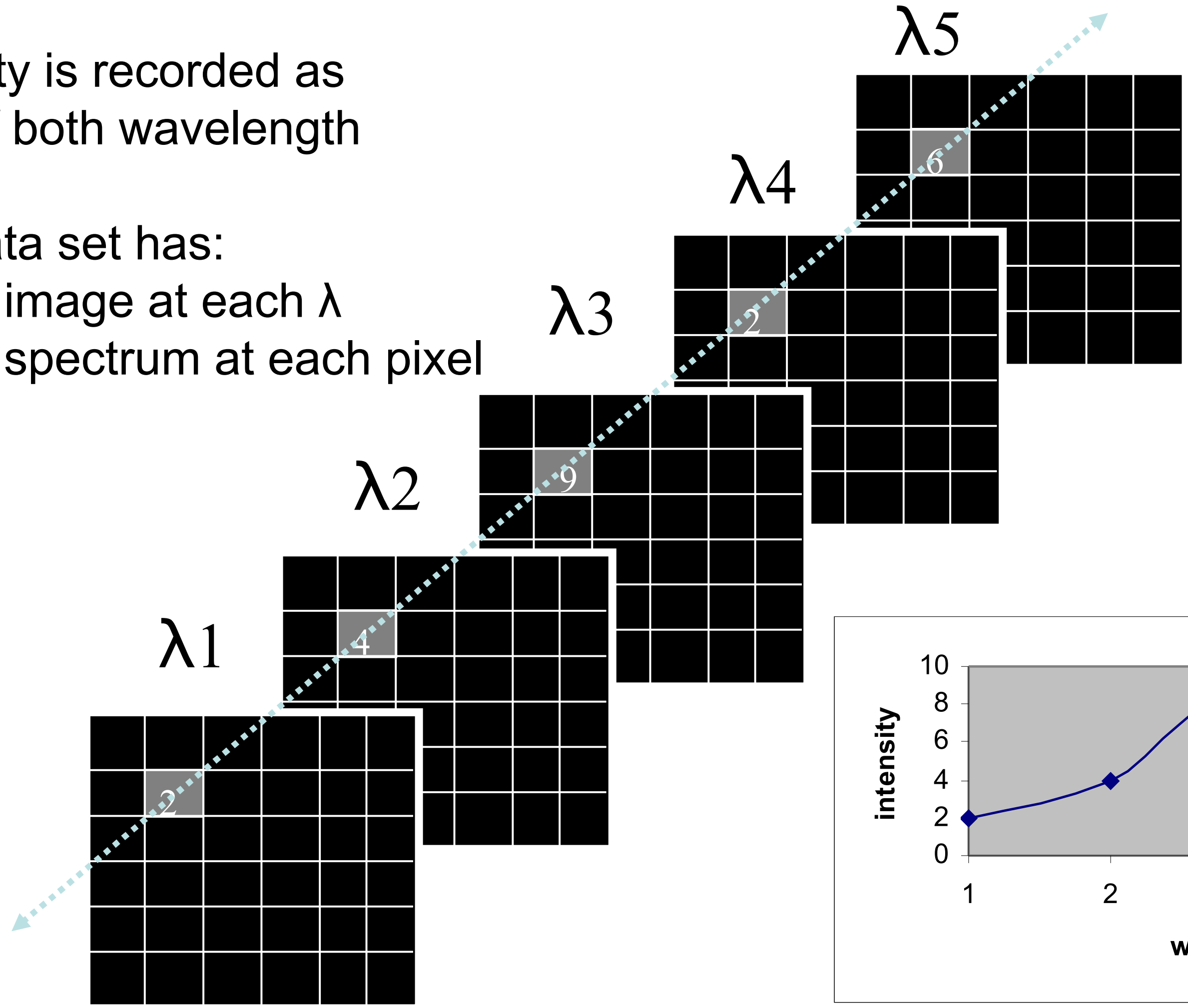
- Hyperspectral (chemical) Imaging – *Combines two sets of information (morphology and spectrocopic)*
- Isotope ratio MS – *Potentially improves the discrimination to the extreme*
- Lab-on-a-chip – *Brings the lab to the scene*

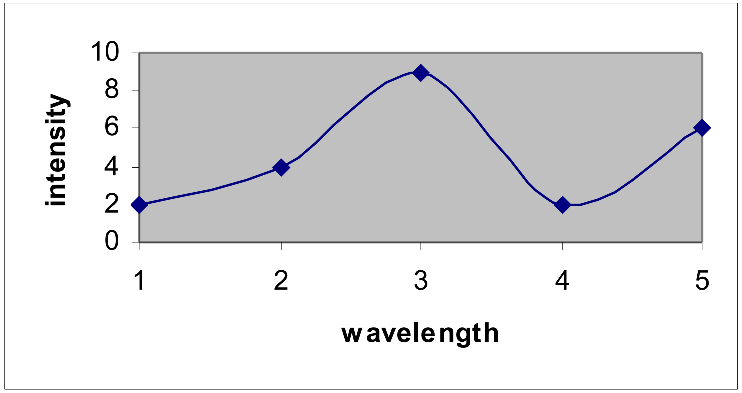
Hyperspectral (Chemical) Imaging

Light intensity is recorded as a function of both wavelength and location

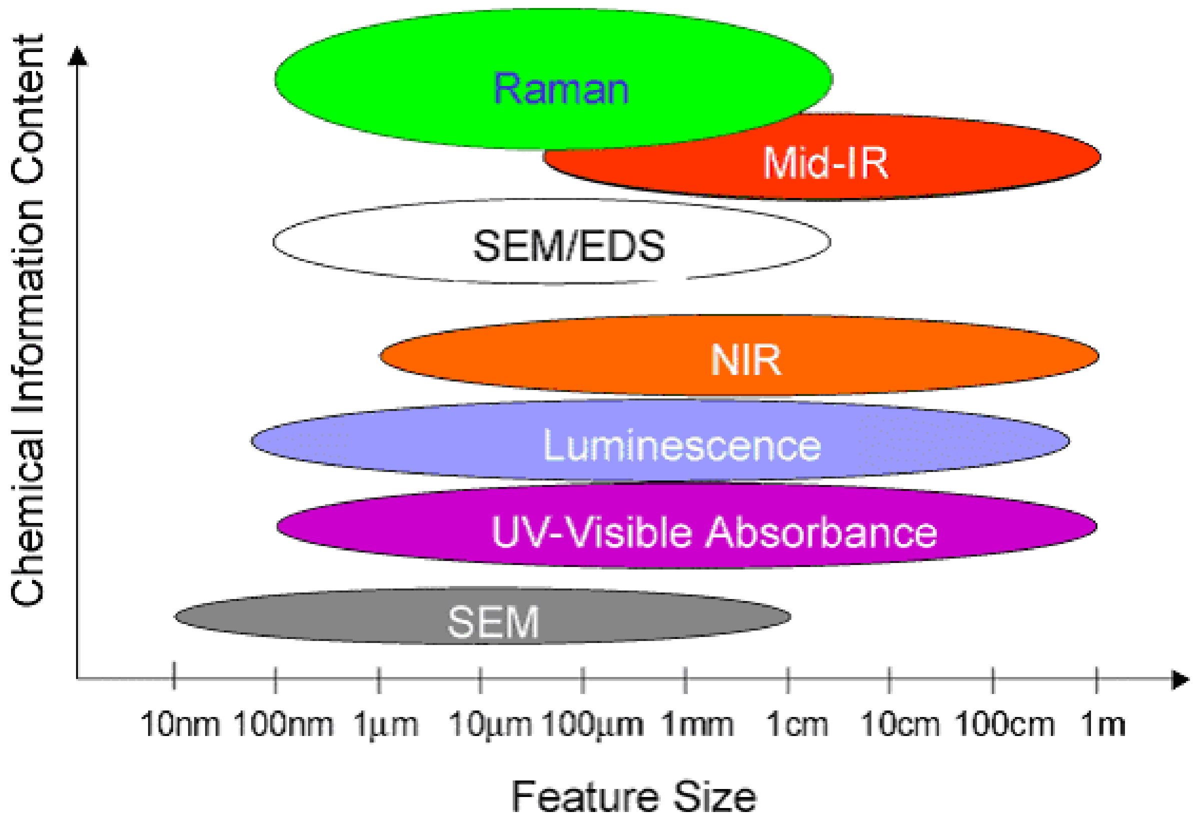
Resulting data set has:

- full image at each λ
- full spectrum at each pixel





Exline, D. L.; Nelson, M. P.; Smith, R. D.; Treado, P. J.; "Forensic Examination of Synthetic Fibers Using Raman Chemical Imaging"; Presented at The Pittsburgh Conference, New Orleans, LA, March 2001



Treado, P., ChemicalImaging Short Course, Webpage: http://www.chemimage.com, 1999

Advantages in Forensic Science

- Non Destructive
- Fast analysis time
- Uses well established, peer reviewed techniques
- Does the job of several instruments
- Minimum sample preparation required
- Side by side comparison and presentation of results

Some Applications

- **Ballpoint and rollerball pen ink analysis**
- **Firearm propellant fluorescence analysis**
- **Fibre analysis**
- **Objective bruise aging**
- **Latent fingerprint enhancement**

Gemma Payne, Christie Wallace, Brian Reedy, Chris Lennard, Rebecca Schuler, David Exline and Claude Roux, Visible and near-infrared chemical imaging methods for the analysis of selected forensic samples, Talanta, Volume 67, Issue 2, 15 August 2005, Pages 334-344.

Instrumentation

Condor

- **Chemical Imaging Macroscope (400nm-1100nm)**
- **Visible, Near Infrared Chemical Imaging**
- **Large samples (fingerprints, questioned documents)**
- **Located at Australian Federal Police**

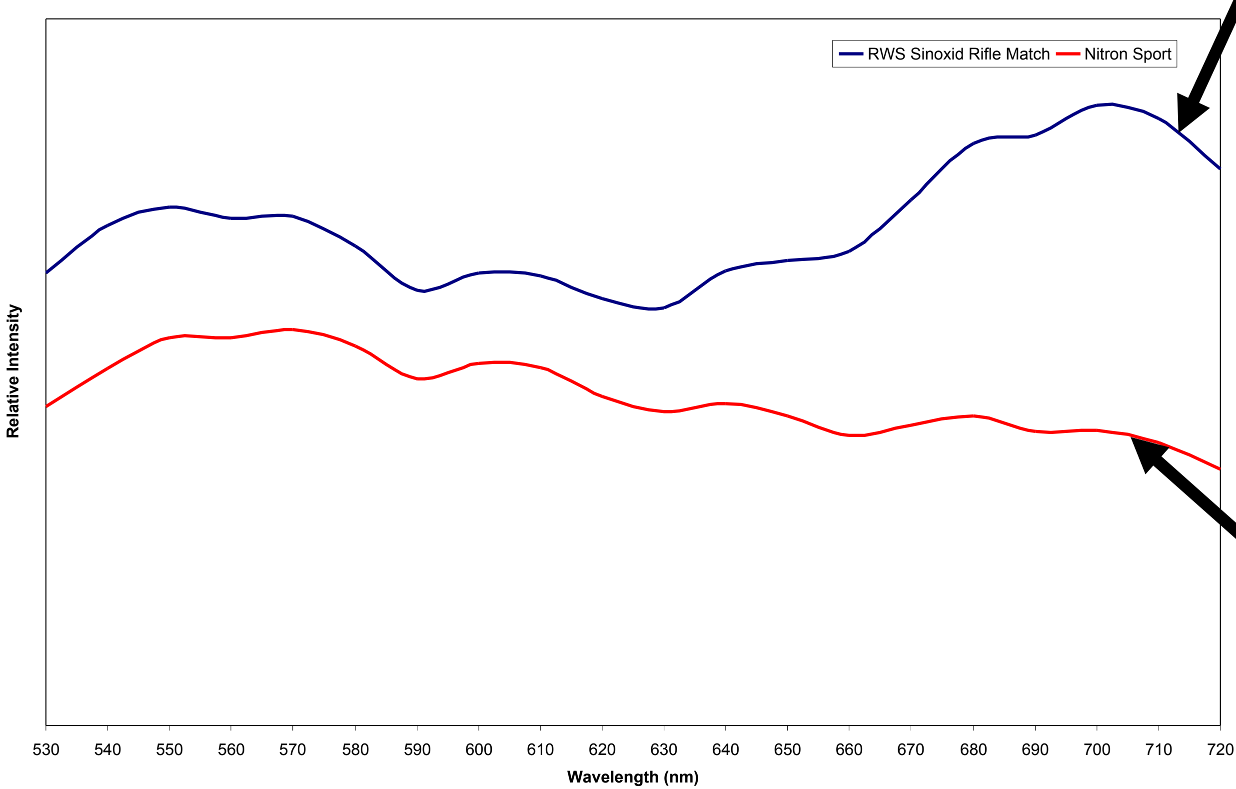
CI Trace

- **Chemical Imaging Microscope (400nm-720nm)**
- **Visible Chemical Imaging**
- **Trace evidence samples**

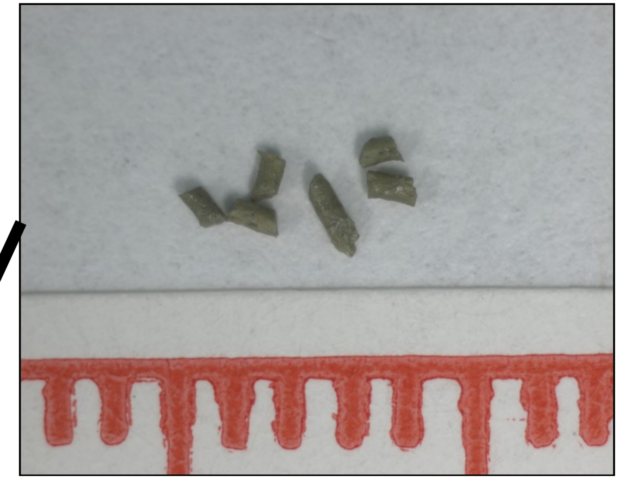
Located at ChemImage (USA)

FTIR: See below; located at UTS

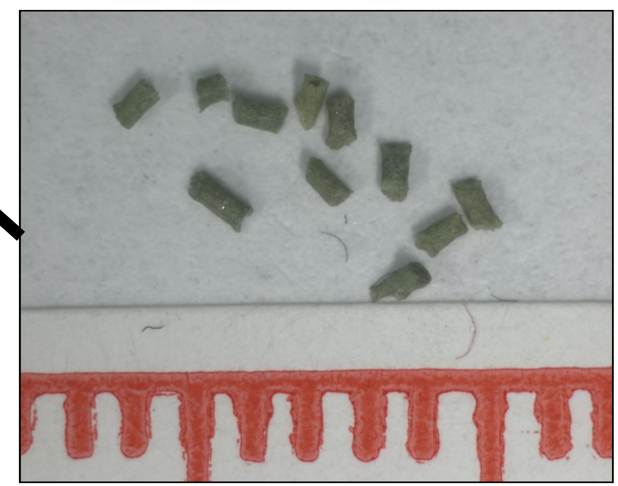
Discrimination of two propellants that visually appear similar (green extruded tubular)



Uncorrected emission spectra comparison of propellant (450nm extraction)



RWS Sinoxid Rifle Match

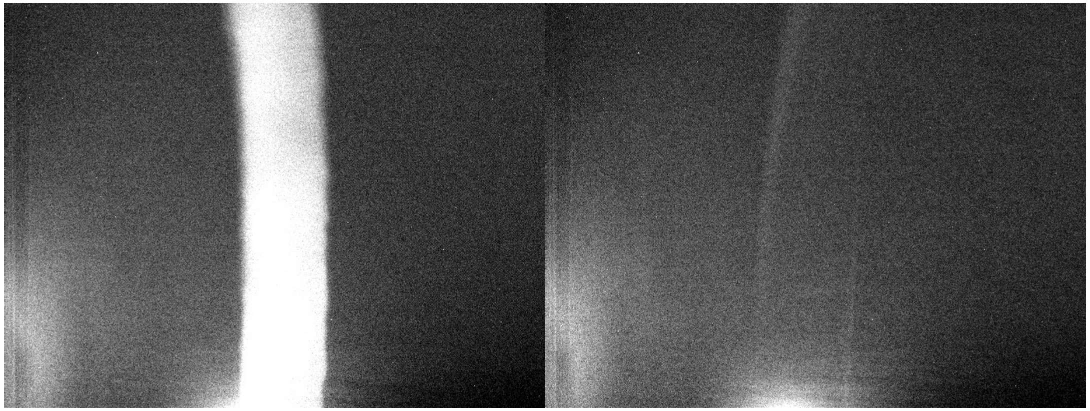


Nitron Sport ammunition

G. Payne et al., Detection and Analysis of Firearm Propellants by Fluorescence Chemical Imaging, Poster, NIJ Trace Evidence Symposium

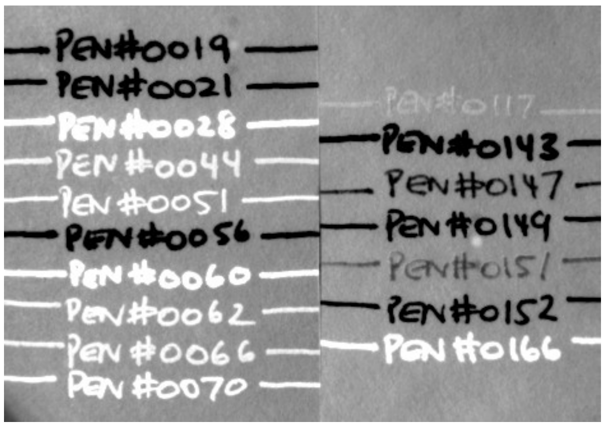
Fibres

Two Different Red Fibres at 550nm Showing Fluorescence Differences

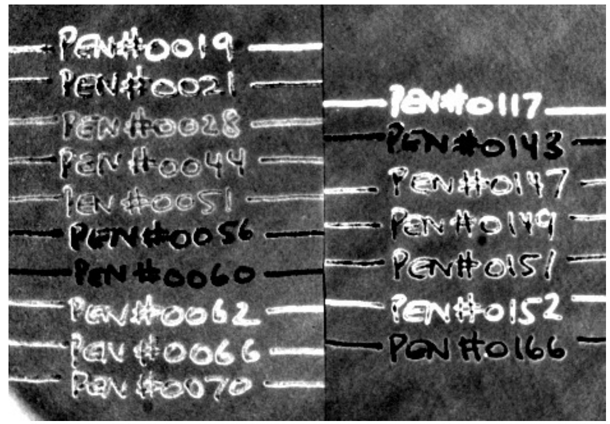


- **The CI-Trace and two microspectrophotometers all provided high degrees of discrimination of red and black fibres.**
- **The microspectrophotometers demonstrated their superior ability to analyse fibres in transmittance mode**
- **The CI-Trace, however, was able to discriminate more fibres in fluorescence mode**

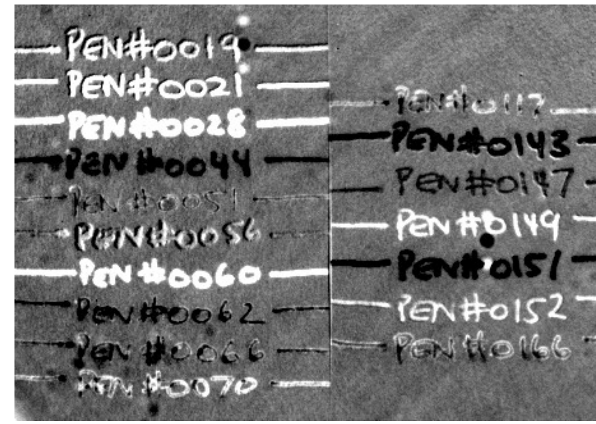
Results – Blue Rollerball Pens (white light excitation)



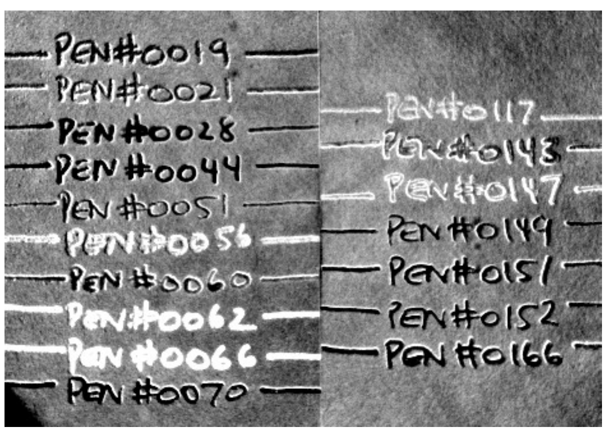
2nd



3rd



4th



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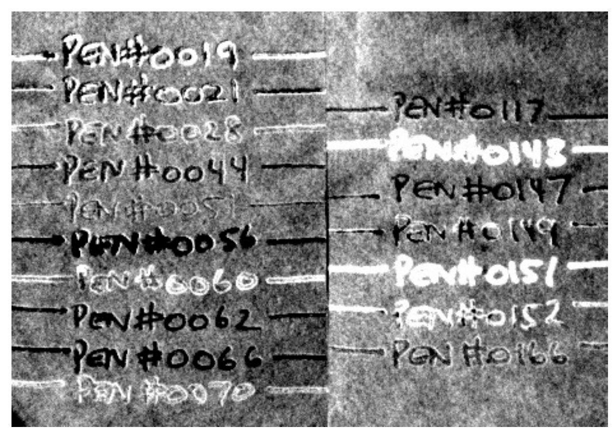


7th

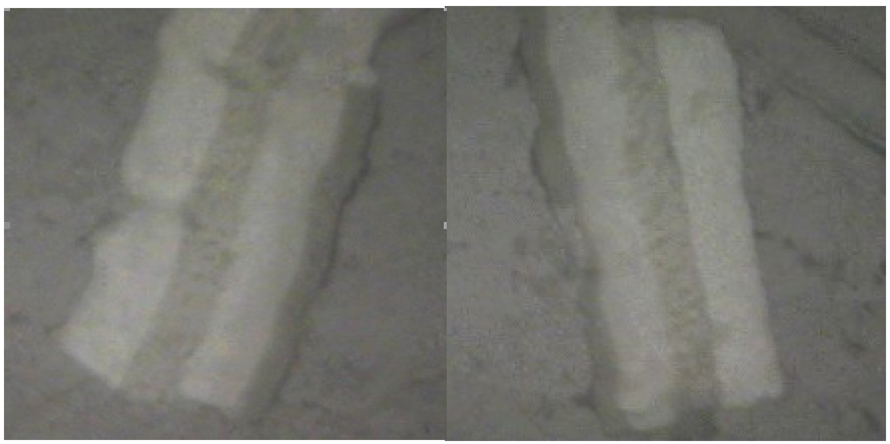
PCA

FTIR Chemical Imaging

- Infrared bench and microscope with an additional detector for imaging
- Detector is a focal plane array (FPA), often 64 × 64 = 4096 detectors (pixels)
- Large sample accessory

Multilayer paint chips

Flynn K., O'Leary R., Lennard C., Roux C., Reedy B.J., Forensic applications of infrared chemical imaging: multi-layered paint chips, Journal Of Forensic Sciences, 50 (4), 2005, 832-841.

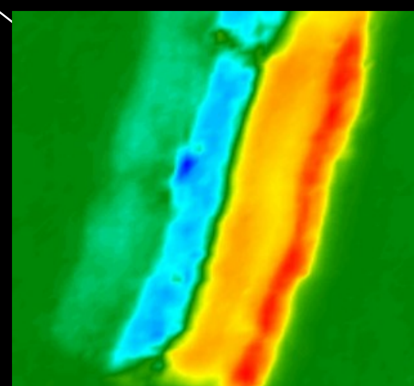


White light (colour!) images

(paint chips embedded in KBr)

Mosaic of two FTIR images; 2nd derivative spectra clustered using supervised classification in ENVI (Mahalanobis distance) acrylic-urethane enamel

acrylic-alkyd-? + talc



acrylic-melamine enamel

acrylic-melamine + $BaSO_4$

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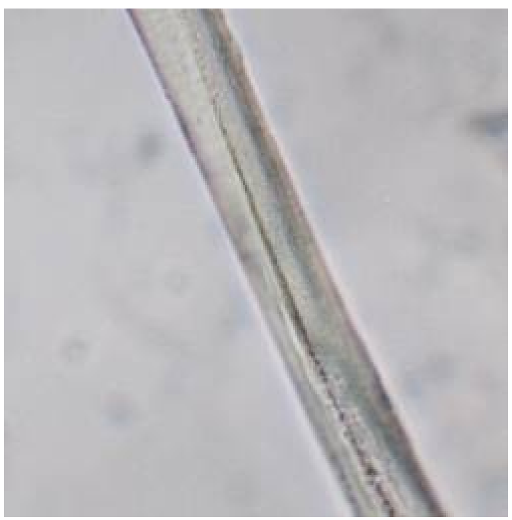
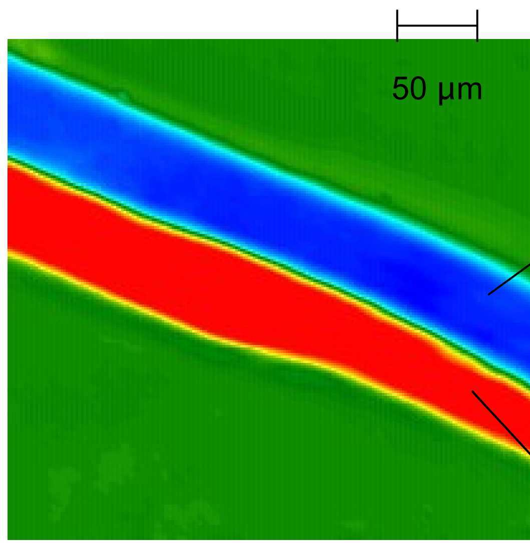
Bicomponent Fibre Analysis (Monvelle Monsanto)

Flynn K., O'Leary R., Roux C., Reedy B.J., Forensic Analysis of Bicomponent Fibers Using Infrared Chemical Imaging, Journal of Forensic Sciences, 51(3), 2006, 586-596.

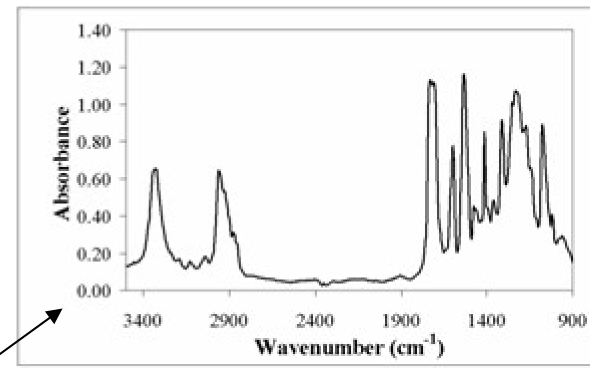


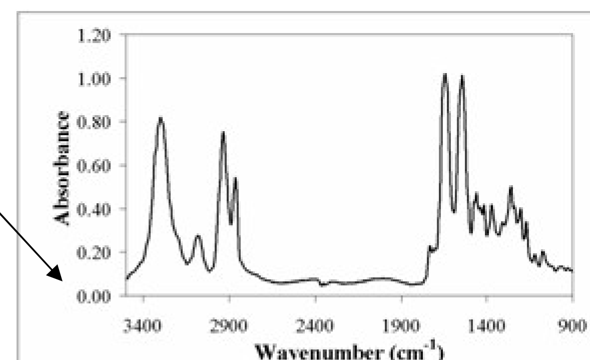
visible image



Infrared image (1641 cm^{-1})

Polyurethane





Nylon

Contaminants in fingerprints

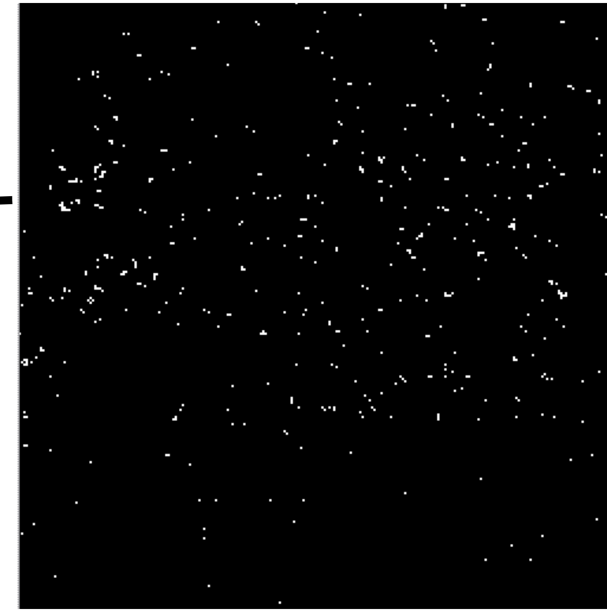
— collect image (~1 x 1 cm) of suspect's fingerprint on silicon window 65536 spectra (pixel size = 44 µm)

— create spectral library from image spectra and search with reference spectra of illicit substances (drugs, explosives, GSR, etc)

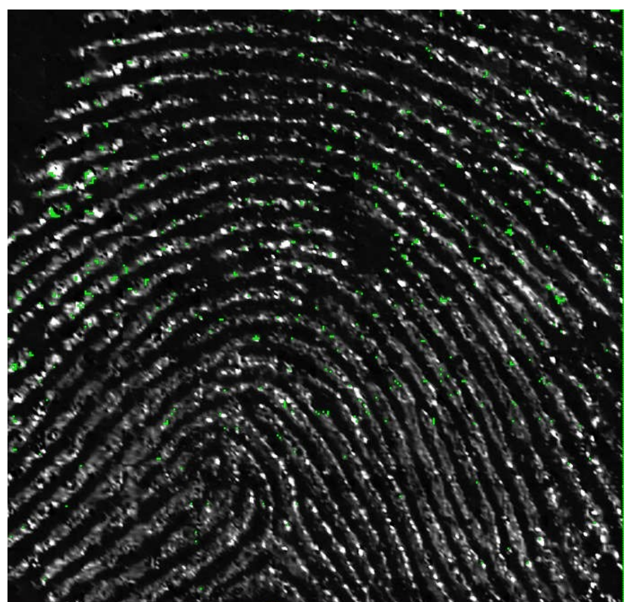
— create "hit-map" of location of substances in fingerprint

PETN (explosive) within fingerprint

FTIR chemical image of fingerprint



FTIR chemical image of PETN (pixels have FTIR spectra with library match for PETN)



Location of explosive PETN in fingerprint image (green pixels)

M. Tahtouh et al., FTIR Spectral Imaging Applications in Trace Evidence, Poster, NIJ Trace Evidence Symposium

Contaminants in fingerprints

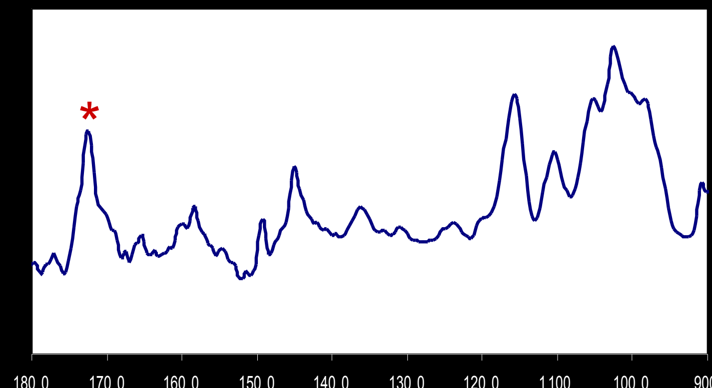
Paracetamol particles deposited with fingerprint

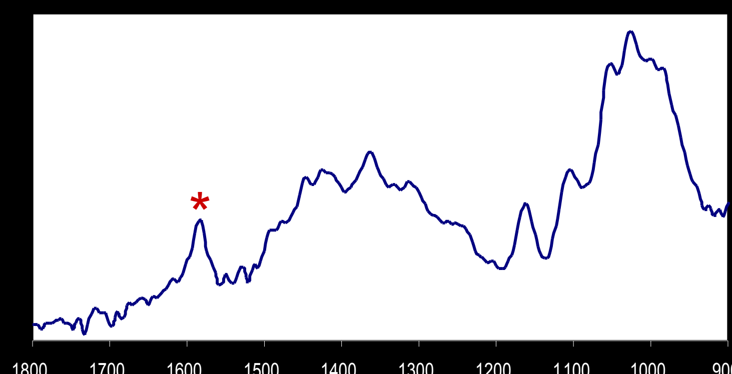
Detection limit < 0.06 µg!

ATR imaging: intersecting lines (ink under toner)

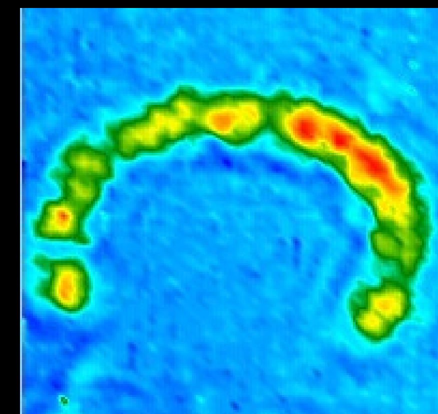
ZnSe macro ATR

Visible Image

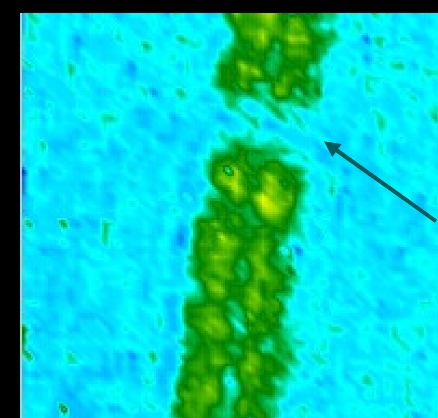




Katherine Flynn's PhD project, UTS



Toner image (1724 cm^{-1})

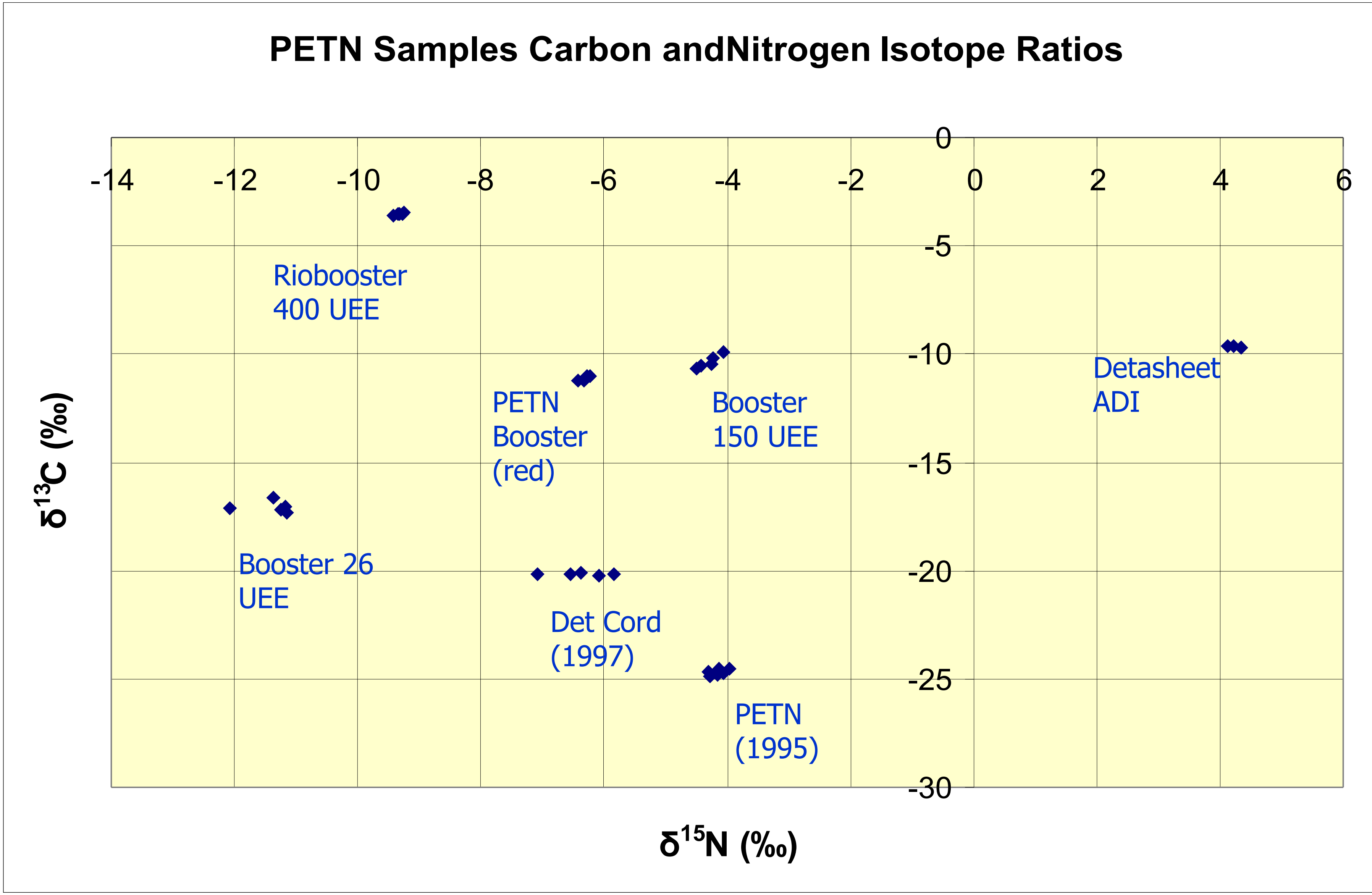


Ink image (1583 cm^{-1})

IRMS - Explosives

- *Benson S., Lennard C., Maynard P., Roux C., The Analysis of Explosives by Isotope Ratio Mass Spectrometry, 18th International Symposium on the Forensic Sciences, 2 - 7 April 2006, Fremantle*
- Current techniques employed for the analysis of explosives and other forensic samples generally cannot distinguish one source of a substance from another.
- At present, if explosives are analysed and can't be differentiated, it is concluded that they are chemically the same substance.
- However, could they have originated from different sources?
- Isotope ratio mass spectrometers (IRMS) are highly specialised mass spectrometers that measure the variations in natural isotopic abundance of the light stable isotopes of C, O, H, N, S.
- Preliminary research has been conducted indicating that different sources of a range of different types of explosives can be differentiated using IRMS.

Preliminary PETN Results



Research Objectives – Sarah Benson's PhD

- Method development & validation (N, O and H)
- Determine whether bulk stable isotope analysis could be utilised to differentiate between:
  - ammonium nitrate from the one manufacturer manufactured over time
  - ammonium nitrate from different manufacturers
- Determine whether samples retain their isotopic composition after an explosion
- Develop a database – Australia and South East Asian region
- Future focus: peroxide explosives and organic high explosives

Lab-on-a-Chip Technology for Explosives Detection

Beavis A., Doble P., Spikmans V., Maynard P., Dawson P., Roux C., Coumbaros J., Lennard C., Rapid Analysis of Selected Organic Explosives Using Lab-on-a-Chip Technology, 17th Meeting of the International Association of Forensic Sciences. Hong Kong, 323, August 2005.

- Growing need for field portable instrument to detect explosives
- Need to improve on-site detection capabilities:
  - Screening device
  - Detection of post-blast residue
- Utilises micro-fabrication technology to miniaturise and integrate laboratory processes
- The 'chips' contain a network of interconnected channels and reservoirs
  - Advantages of LOC technology:
  - Rapid analysis time
  - Minimal reagent consumption (µL)
  - <u>Potential for portability</u>

The Agilent Bioanalyzer

— The first commercially available instrument to employ CE-based LOC technology

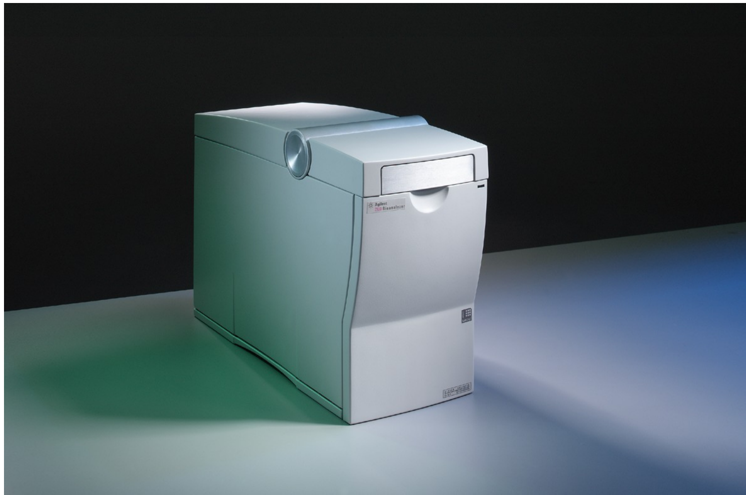
— The "Bioanalyser" was designed for life science applications

— Red laser fluorescence detection system:

- Excitation: 630nm
- Emission: 680nm

— Explosives are known to quench fluorescence:

- Detection can be achieved by addition of a suitable dye to the electrolyte
- The explosives are detected by a decrease in the fluorescence signal



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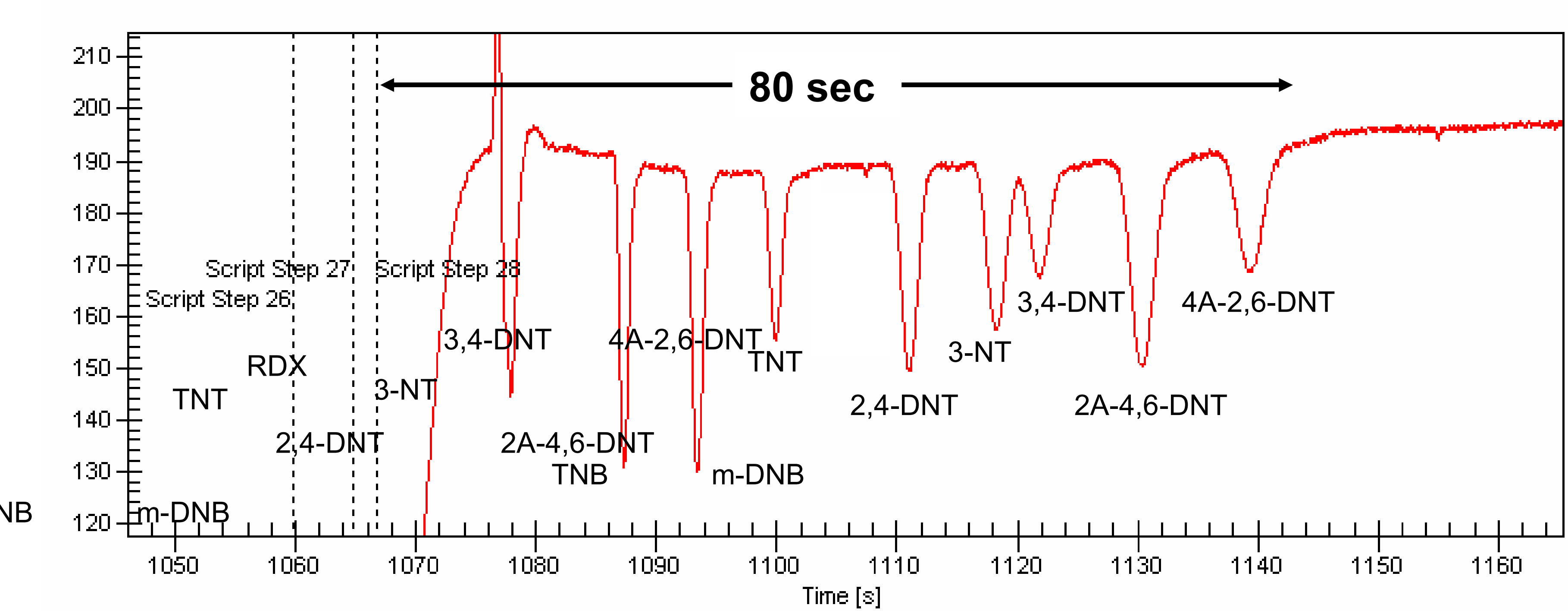
Detection of Organic Explosives



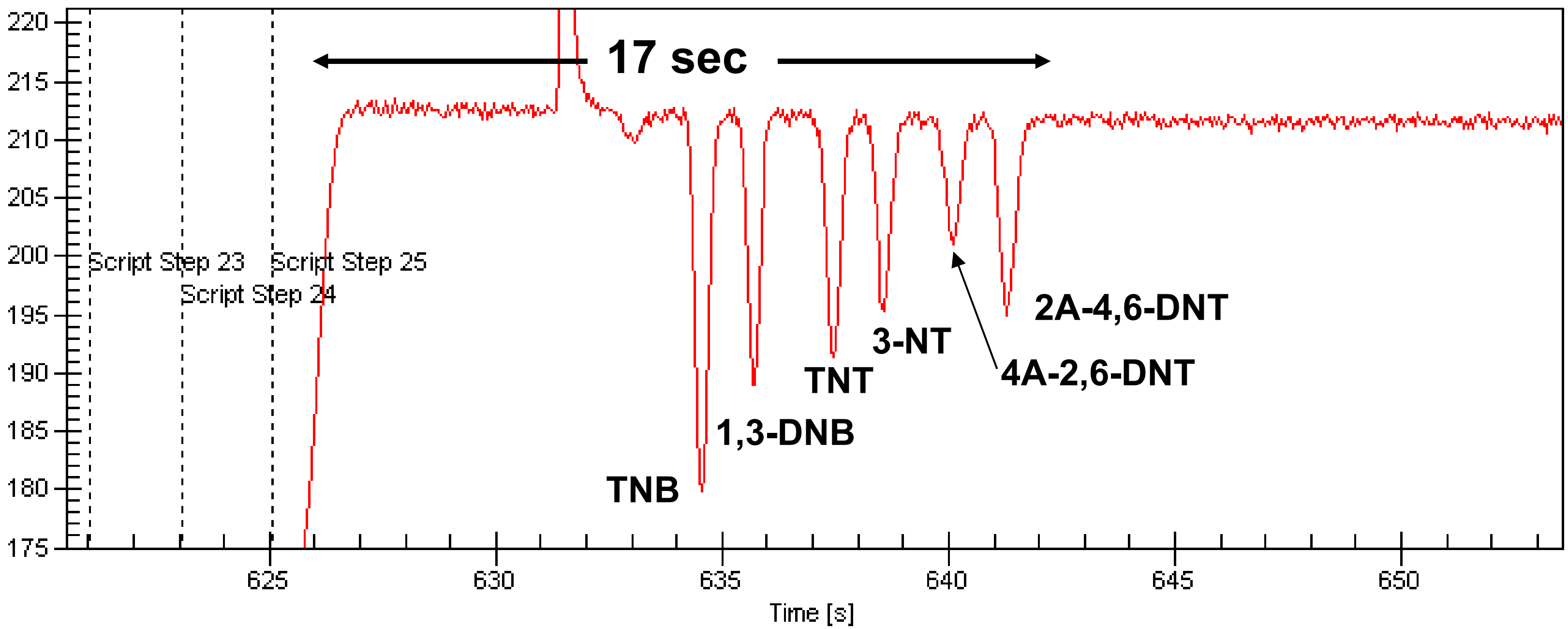
<u>Electrolyte:</u>

50mM SDS

50mM Borate

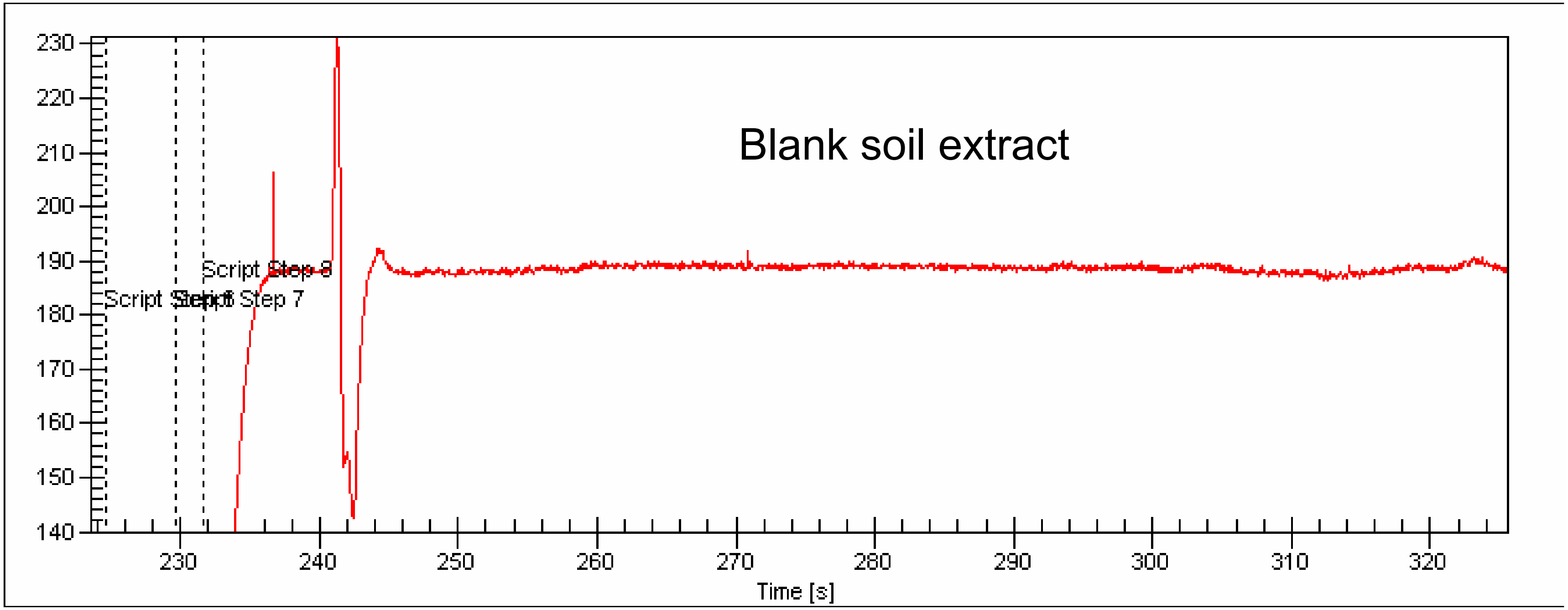
1.5% AgilentTM Dye (v/v)

Detection of Organic Explosives

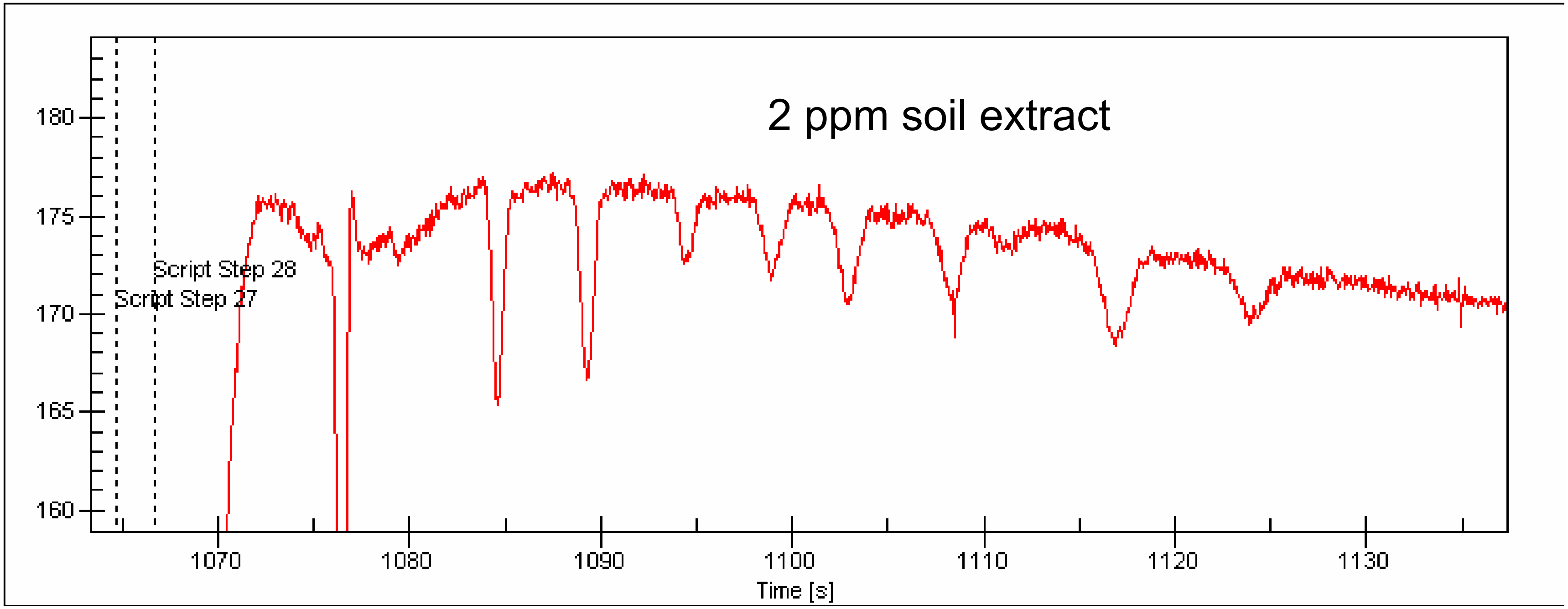


Electrolyte

50mM Borate & 25mM SDS with 1.5% Agilent DNATM Dye

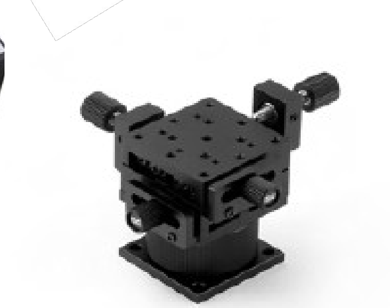


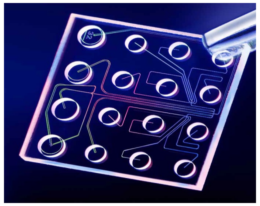
Blank soil extract
Script Step 8
Script Step 6
Script Step 7
230
220
210
200
190
180
170
160
150
140
230
240
250
260
270
280
290
300
310
320
Time [s]



2 ppm soil extract
Script Step 28
Script Step 27
180
175
170
165
160
1070
1080
1090
1100
1110
1120
1130
Time [s]

Hand-held Device Fabrication





Discussion

— Economic realities and the change of status of trace evidence = significant challenges for this discipline.

— Need to re-assess the place and shape of trace evidence, as well as the need to think about new models applicable to trace evidence.

— The successful re-emergence of trace evidence in the 21st Century will depend on:

- The end of ultra-specialisation and a return to the generalist approach
  - Trace evidence experts with a holistic view of forensic science will optimise the value that can be drawn from trace evidence, both from court and intelligence viewpoints.
- The successful implementation of relevant emerging technologies:
  - To be successful, these developments must occur with prime consideration of the forensic context (holistic forensic approach, fit for purpose, etc).

Discussion

- Successful implementation of relevant emerging technologies will:
  - Blur the boundaries between lab and field forensic science.
  - Streamline the analytical process leading to quicker results.
  - Free up the forensic scientist who can in turn have more time to spend on difficult cases, background survey assisting the interpretation, etc., leading to more meaningful results.
- The realisation that discrimination is not the most significant feature for trace evidence:
  - Trace evidence is a value-added source of information for the reconstruction of a case, or, more broadly, for investigative purposes. The combination of trace evidence with ‘identifying evidence’ can deliver the key to the famous questions “what happened?” and “who dun it?”.

Discussion

- A more general engagement with the DNA and the fingerprint disciplines:
  - These two other types of evidence are essentially trace evidence in nature. They rely on the transfer, persistence, detection, collection and successful examination of material.
  - Many of the issues, and also solutions, are very similar for all three disciplines.
  - A more coherent approach will benefit all three disciplines and, in turn, forensic science as a whole.

Conclusions

— Overall, the future of trace evidence is much brighter than one might think.

— We must to face the challenges, seize the opportunities and convince the stakeholders that trace evidence plays a crucial role in law enforcement and in the administration of justice.

— Implementing the right strategic directions will not only ‘save’ trace evidence, but also prompt its re-emergence.

Acknowledgments

— NIJ for the invite

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— National Security Science & Technology Unit (Aus)

— NSW Police Service