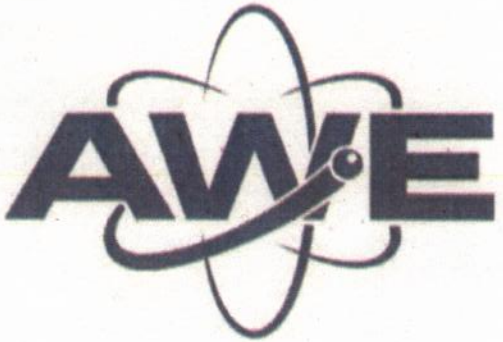
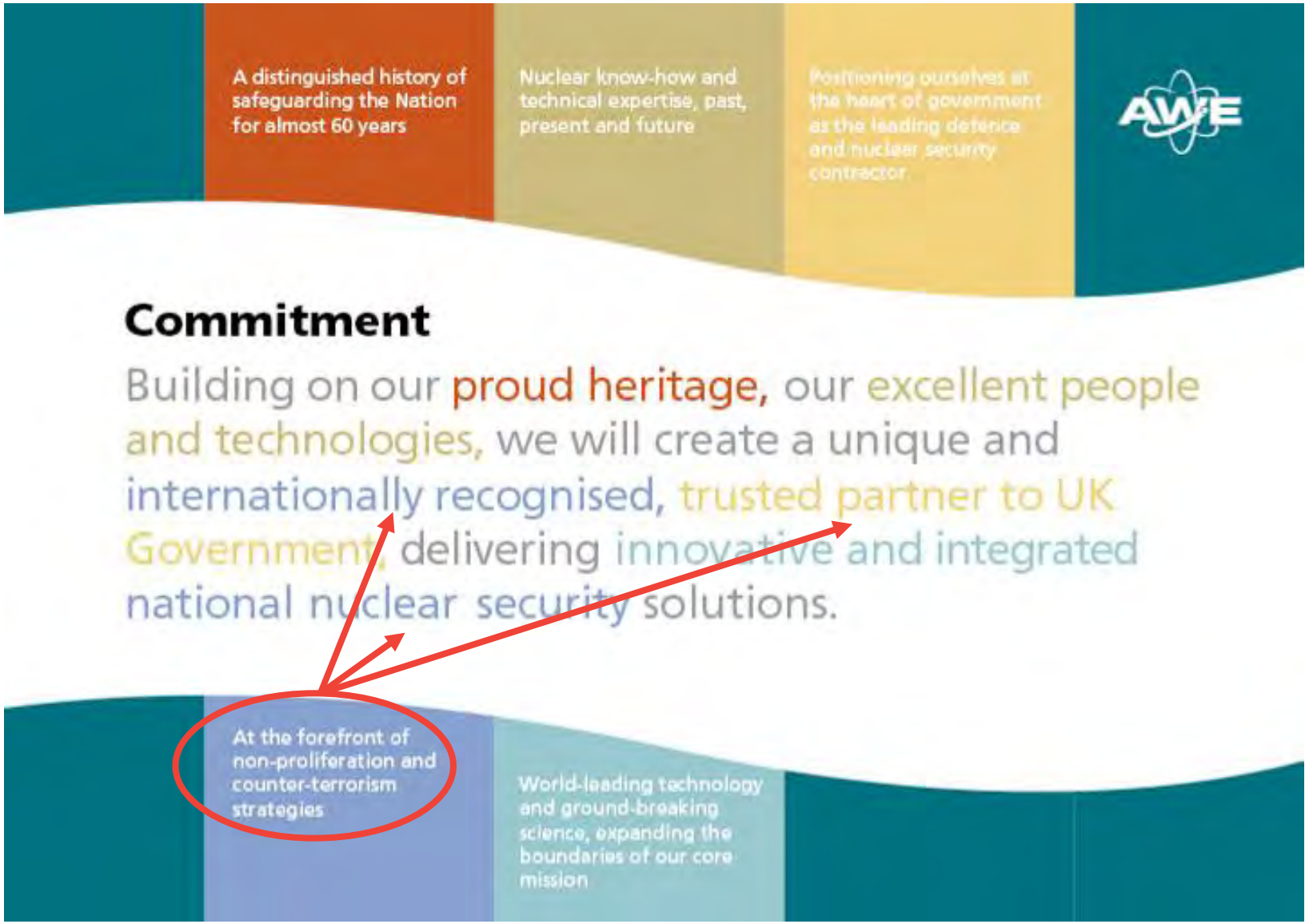


Material detection, characterisation and verification science

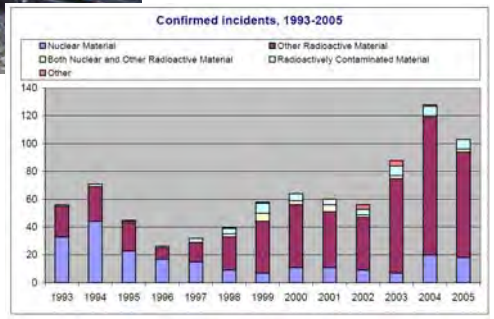
[redacted]

National Nuclear Security

Doc Control Number


A distinguished history of safeguarding the Nation for almost 60 years
Nuclear know-how and technical expertise, past, present and future
Positioning ourselves at the heart of government as the leading defence and nuclear security contractor
Commitment
Building on our proud heritage, our excellent people and technologies, we will create a unique and internationally recognised, trusted partner to UK Government, delivering innovative and integrated national nuclear security solutions.
At the forefront of non-proliferation and counter-terrorism strategies
World-leading technology and ground-breaking science, expanding the boundaries of our core mission

The Radiological and nuclear threat

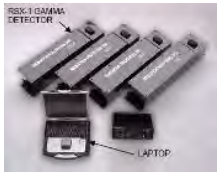


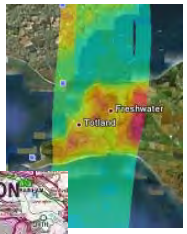
- Terrorist threats to UK interests (1) .
- Terrorist interests in SNM and radiological material(1).
- Concern over accessibility of SNM and Radiological materials(1).
- Recognition of 100's of cases of SNM and radiological material being intercepted(2).
- Particular concerns(1)
  - Nuclear Terrorism
  - Balance of CP and CT response and capabilities

(1) *The National Security Strategy of the United Kingdom; Security in an interdependent world. Cabinet Office 2008*
(2) *IAEA Illicit Trafficking Database.*

AWE provides support to UK national security capability and provision of Nuclear Accident capability

- Support national emergency arrangements
  - Underpinning technology development
    - Detection
  - Radiological and Nuclear Forensics
    - Characterisation of materials
- Support national treaty obligations
  - Verification science
    - Seismology
    - Radiochemistry
    - Arms Control Verfication

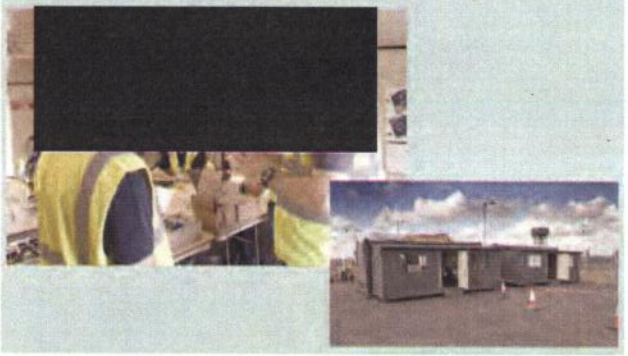

AWE Nuclear Accident Response Organisation (NARO)

- AWE NARO provides a technical and scientific support capability to the UK MOD for post accident/incident assessment, render safe, packaging and transportation of Defence Nuclear Material (DNM) – this includes the Trident Warhead and SNM (Special Nuclear Material)
- Comprises approximately 160 volunteers selected for their specialist knowledge (command and control, technical evaluation and recovery or support capability expertise) from across AWE.
- Provides the capability to:
  - Provide technical and scientific advice on the recovery of DNM following an accident/incident within the UK.
  - Assess, diagnose, recover and package ready for transportation the consequences of an accident involving DNM within the UK.
  - Provide technical and scientific advice on the recovery of US weapons following an accident/incident on UK soil.
  - Support the recovery of SNM and other materials as a result of a Routine Logistics Flight (RLF) incident in the UK or US.
- Capability focussed in three key operational areas:
  - **AWE Home Team:** Provides critical reachback capability -focus on technical assessment to support in-field operations using the totality of AWEs science and engineering knowledge base
  - **In-Field Team (BRONZE):** Focus on weapon assessment and recovery issues, including support to planning and initial screening of military recovery options
  - **Strategic Operations (GOLD):** Senior technical and scientific support to Police and Military command and control operations at strategic HQ (GOLD)
- 24/7 operational capability: self-sufficient for 48 hours to support up to 70 AWE responders in the field.

AWE Nuclear Accident Response Organisation (NARO)

Rapid Warhead Safety and Stability Assessment
The AWE Advance Party provides rapid nuclear safety and warhead stability assessment capability. The team also gather situational awareness evidence/information to support follow on recovery planning and operations.

Technical Recovery Task Planning and Assessment
Technical Recovery Task Planning and Assessment activities are undertaken by the Technical Recovery Group within AWE's secure Mobile Accommodation Units (MAU) utilising the AWE 'Home' team reach-back capability.



Debris Search, Identification and Recovery
Post incident/accident warhead debris search, identification and recovery operations are carried out by In-Field Search Team Specialists under the supervision of a Weapon System Specialist.

Radiographic Diagnostics/Interpretation
The radiography team has the capability undertake non-intrusive radiographic assessment. This is used to provide positive verification of the critical safety features of a damaged warhead to support post incident nuclear safety and stability assessment and follow on technical recovery task planning activities.

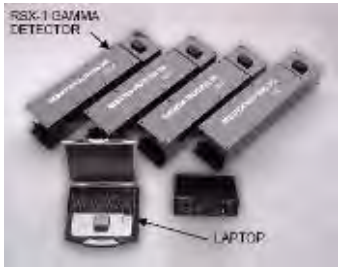
Warhead processing/render safe operations
Capability to undertake in-field warhead processing operations to support warhead stabilisation and transport operations

Warhead/SNM and Debris Packaging
Specialist recovery packaging teams and container systems are deployed to package any recovered warhead components/debris following an accident/ incident. This includes the capability to support onward transportation safety assessment.


AP SEARCH
H.P.
BAG
INSTRUMENTS
Detection Science

Detection : Support to National Emergency Arrangements

- Unique application of commercial instruments
  - Modification
  - Packaging
  - Detector characterisation
  - Search and detection trials

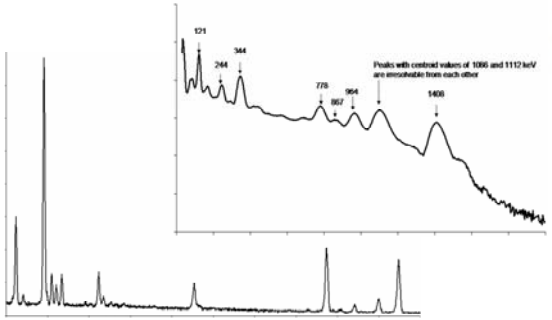


Requirements

- Collaborate cross-government
- Detect and identify threat materials
- Find solutions for use in operational environments
- Tested to Government standards
- Instruments highlighted through Horizon Scanning
- Instruments chosen for testing through down selection process

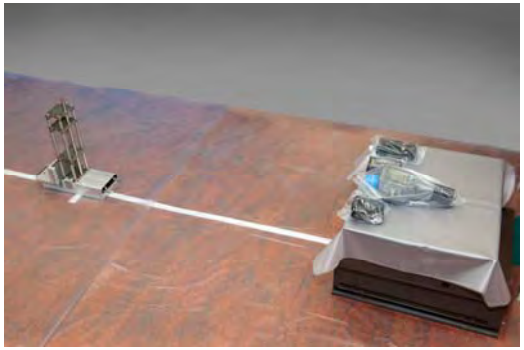
Detector characterisation

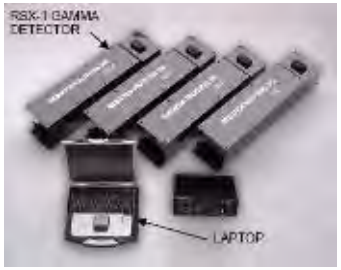
- Typical measurements
  - Absolute/Intrinsic/Relative efficiency
  - Peak to Compton Ratio
  - Energy Resolution
  - Effective gamma energy response
  - Identification of single radionuclides
  - Identification of multiple radionuclides
  - False identification
  - Linearity of response
  - Response Time
  - Statistical Fluctuations
  - Background Indications
  - Overload Performance
  - Photon Energy Response
  - Polar Response
  - Ergonomics
  - Alarm performance
  - Environmental performance
  - Mechanical performance



Search and detection trials

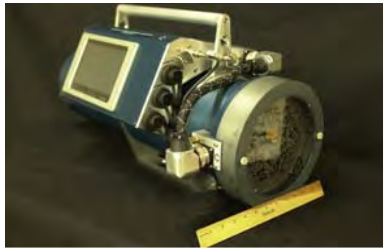
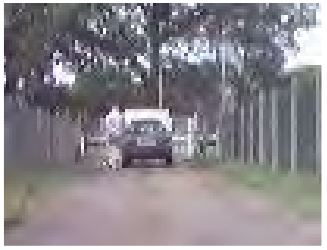
- Tested in representative in operational environments





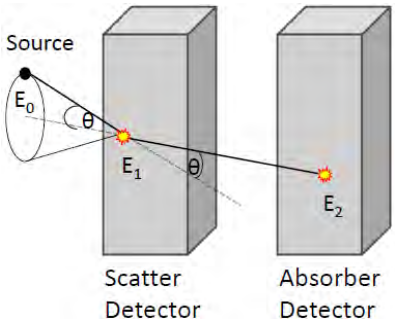
Detection : Gamma Ray Imaging development

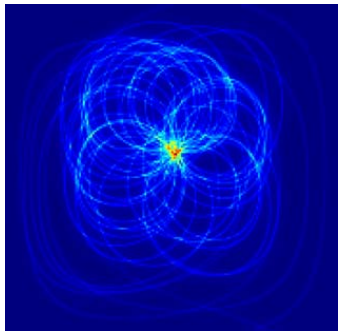
- AWE is working with partners (LLNL and NRL) to consider the application of coded aperture gamma ray imaging systems in UK response.
- This includes hand held assets and large stand off arrays for searching large areas.
- AWE are assessing both the technology but also how this equipment can improve our search and detection capabilities.

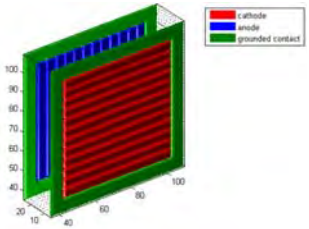
Detection : Gamma Ray Imaging

- Compton imaging investigated for AWE applications
- Collaborative project with the University of Liverpool put in place 2009
- Concept
  - Two Detectors
  - Energy depositions allows angle of scatter
  - Position of interaction give axis of scatter

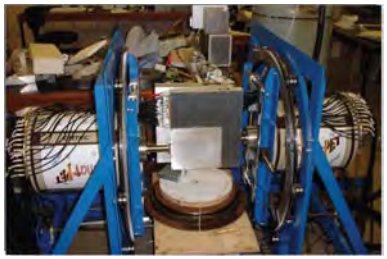




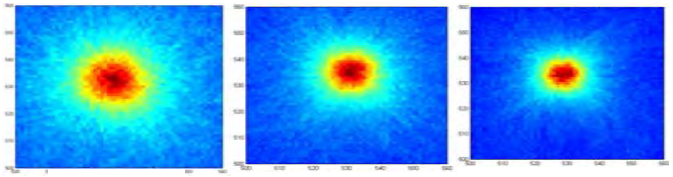
$$\cos\vartheta = 1 - m_e c^2 \left(\frac{1}{E_1} - \frac{1}{E_0} \right)$$



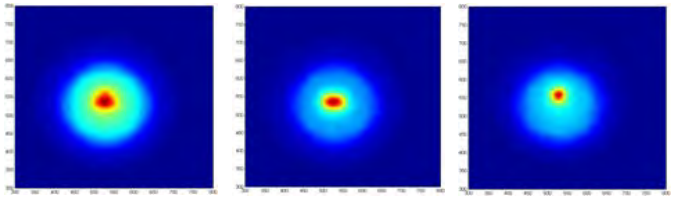
- 2 HPGe planar detectors
  - 12 strips on each side electrically segmented
  - Active volume 60 x 60 x 20 mm3
  - Each strip 5mm wide



- DSSD (Ge): Resolution
  - Energy resolution 1.5 keV @ 122 keV
  - Spatial resolution of 1mm in X and Y
  - Spatial resolution of 5mm in the Z



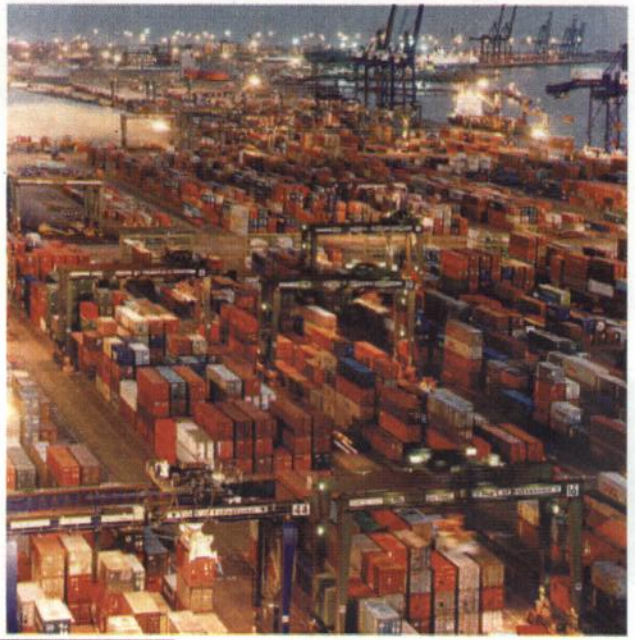
Reducing angular uncertainty by varying separation

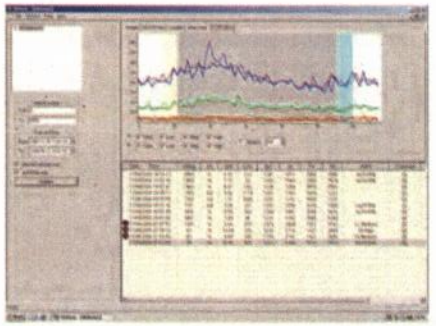


Distinguishing sources through Energy Gating

Detection: Border protection

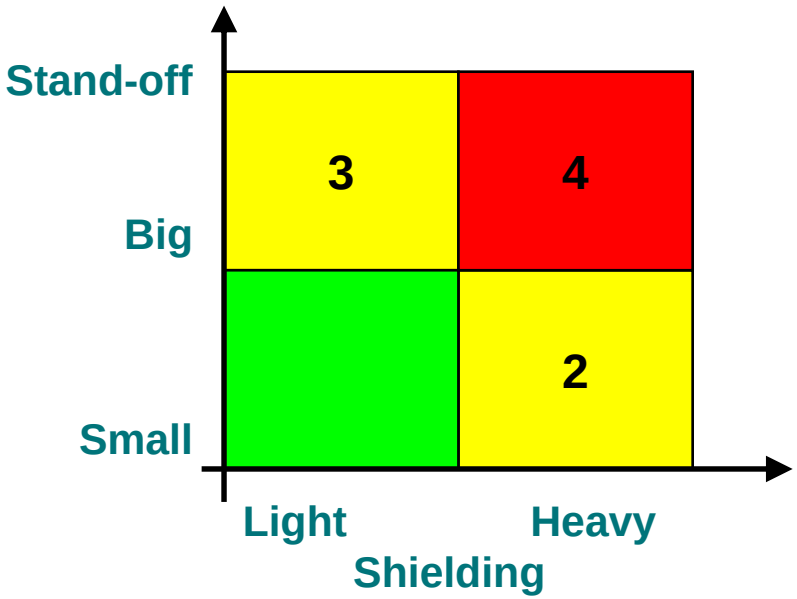
- AWE is Technical Authority (RN) for the portal monitoring project responsible for provision of radiological and nuclear source detection at UK points of entry
- Home Office sponsored
- Partnership with UK Border Agency
- Reachback capability for alarm advice



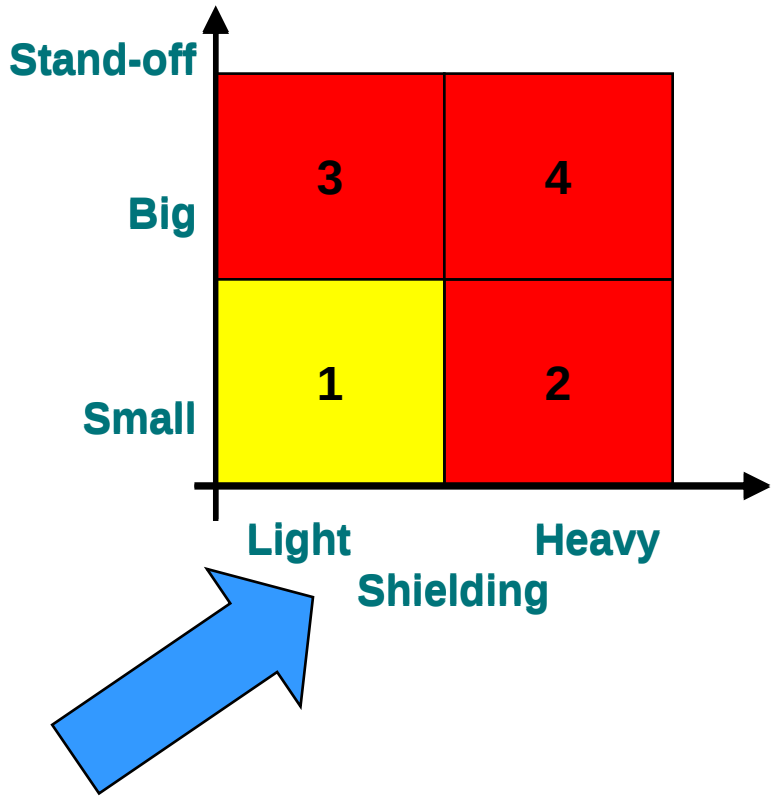


Enhanced Detection

Radiological materials
(e.g. ^{60}Co, ^{137}Cs etc.)

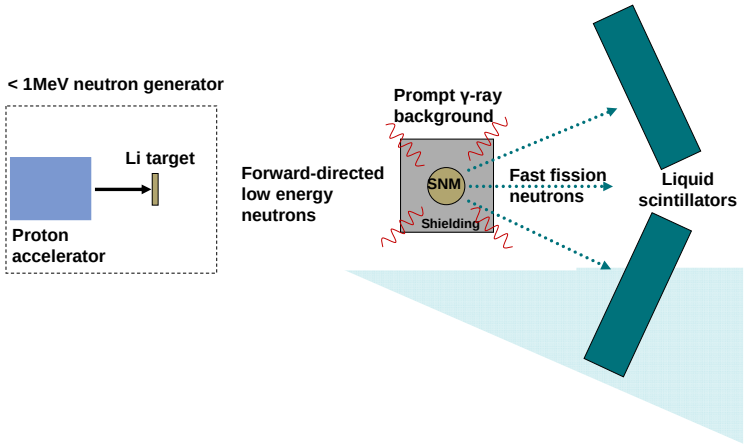


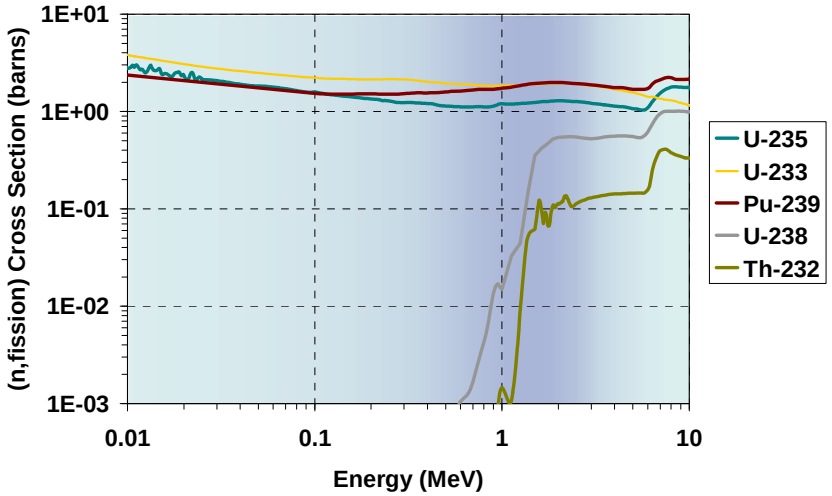
Nuclear materials
(e.g. ^{239}Pu, ^{235}U etc.)

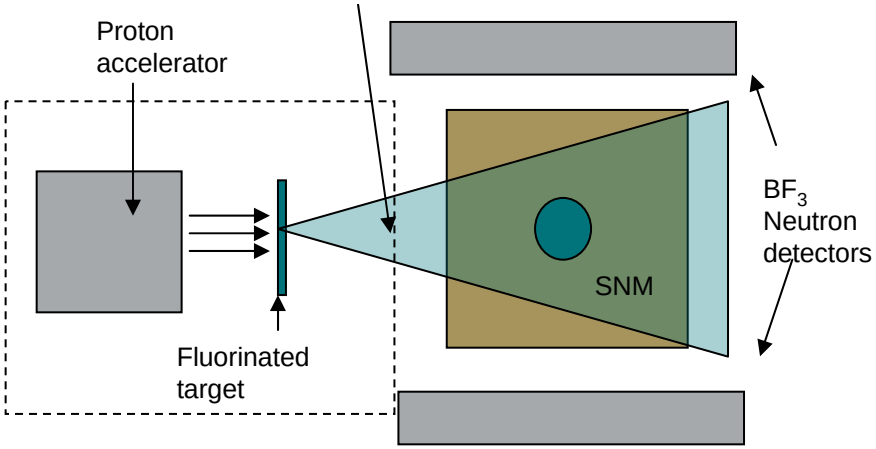


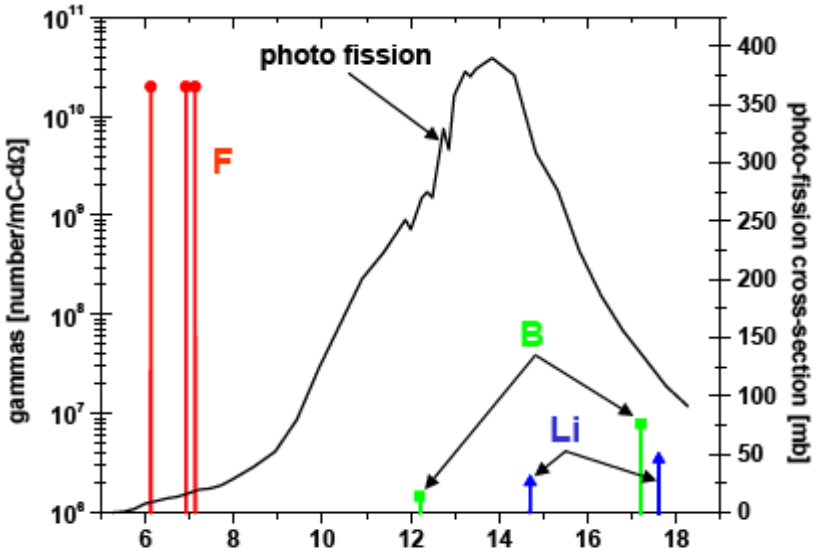
Enhanced Detection

Active Fission Techniques



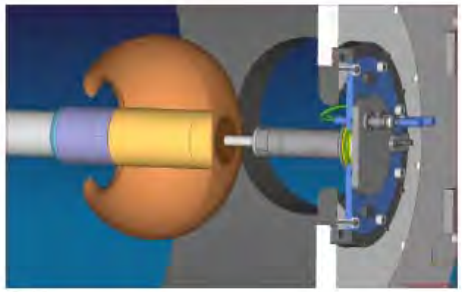


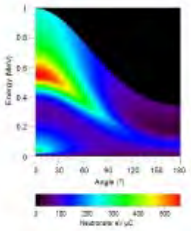


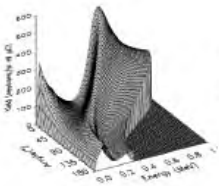


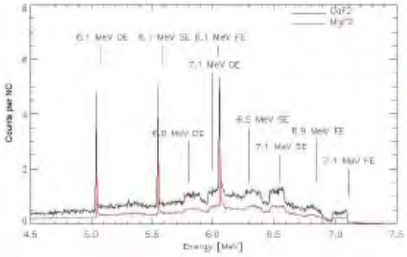
Enhanced Detection

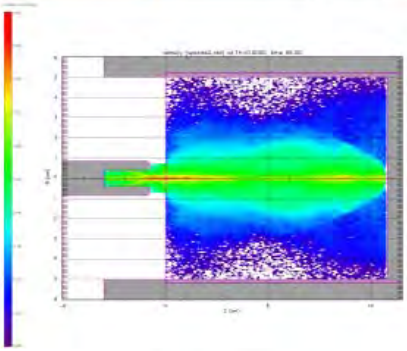
Active detection – sub-system evaluations

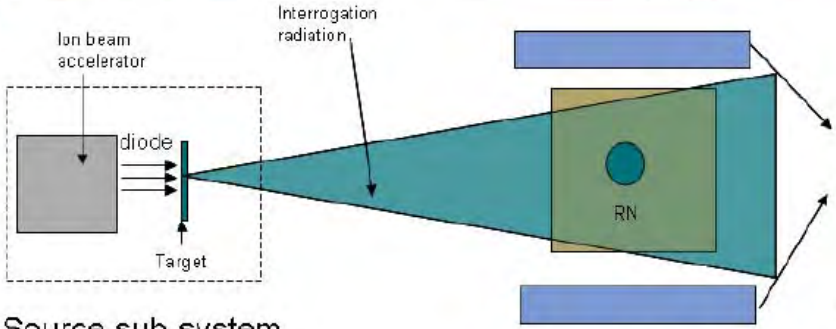


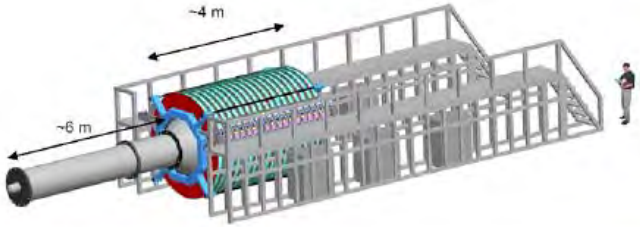


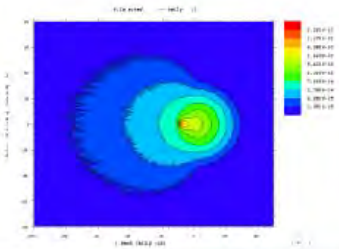












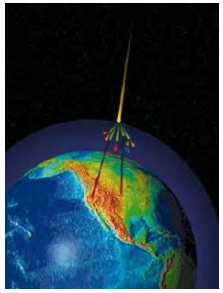
Evaluations on active fission

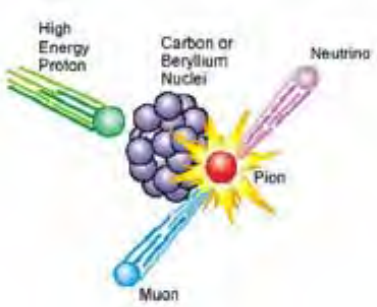
	Interrogating radiation				
Feasibility for detection of X kg WGU	$n(E_1)$	$n(E_2)$	γ (char)	γ (10MeV brems)	Radiological safety
5m bare	G	G	G	G	G
5m shielded	G	G	A	G	G
100m bare	A	A	R	R	G
100m shielded	R	R	R	R	A

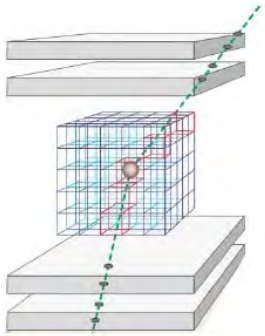
- Detection of kg sized pieces of shielded SNM looks feasible at few m stand off
  - Identified a number of technologies to do this including via ~ 4 man portable, small neutron generators
- Detection at 100m stand off may be possible for bare materials but is unlikely to be feasible for highly shielded material
  - Identified technologies which maximise detection capability – lorry mounted or fixed site technologies

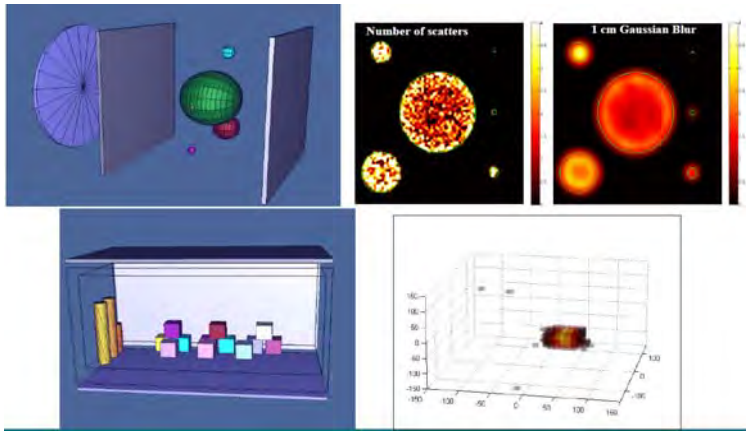
Enhanced Detection

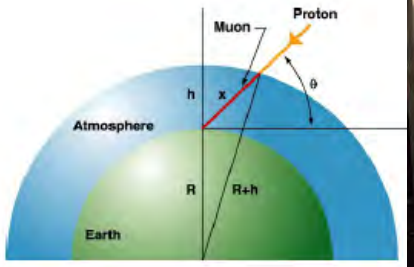
Muon Scattering Tomography

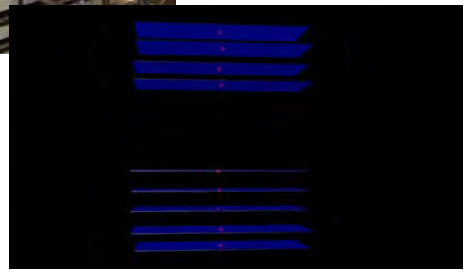


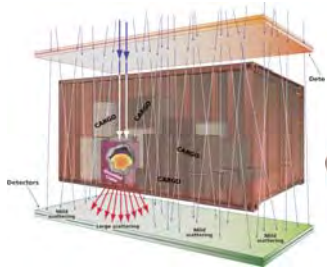








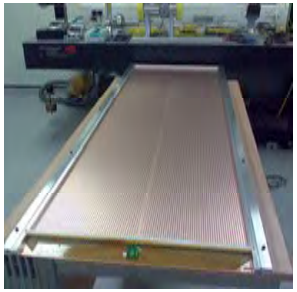


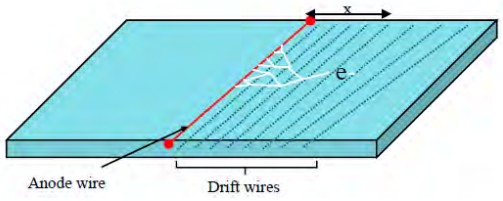


Enhanced Detection

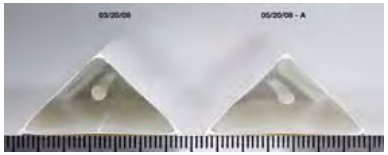
Muon detector technology candidates developed with academia

- Drift chambers

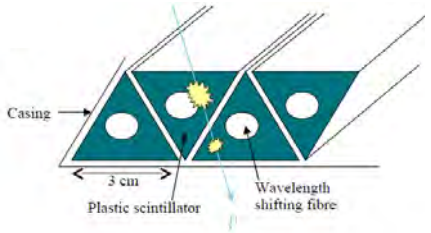




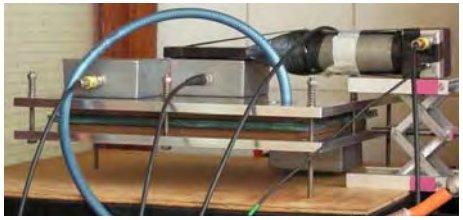
- Scintillating detectors

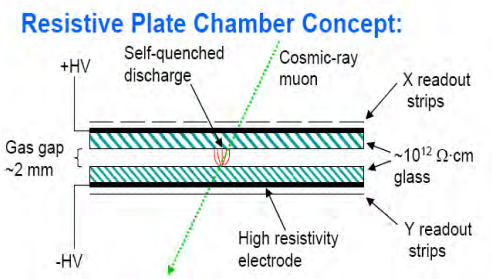


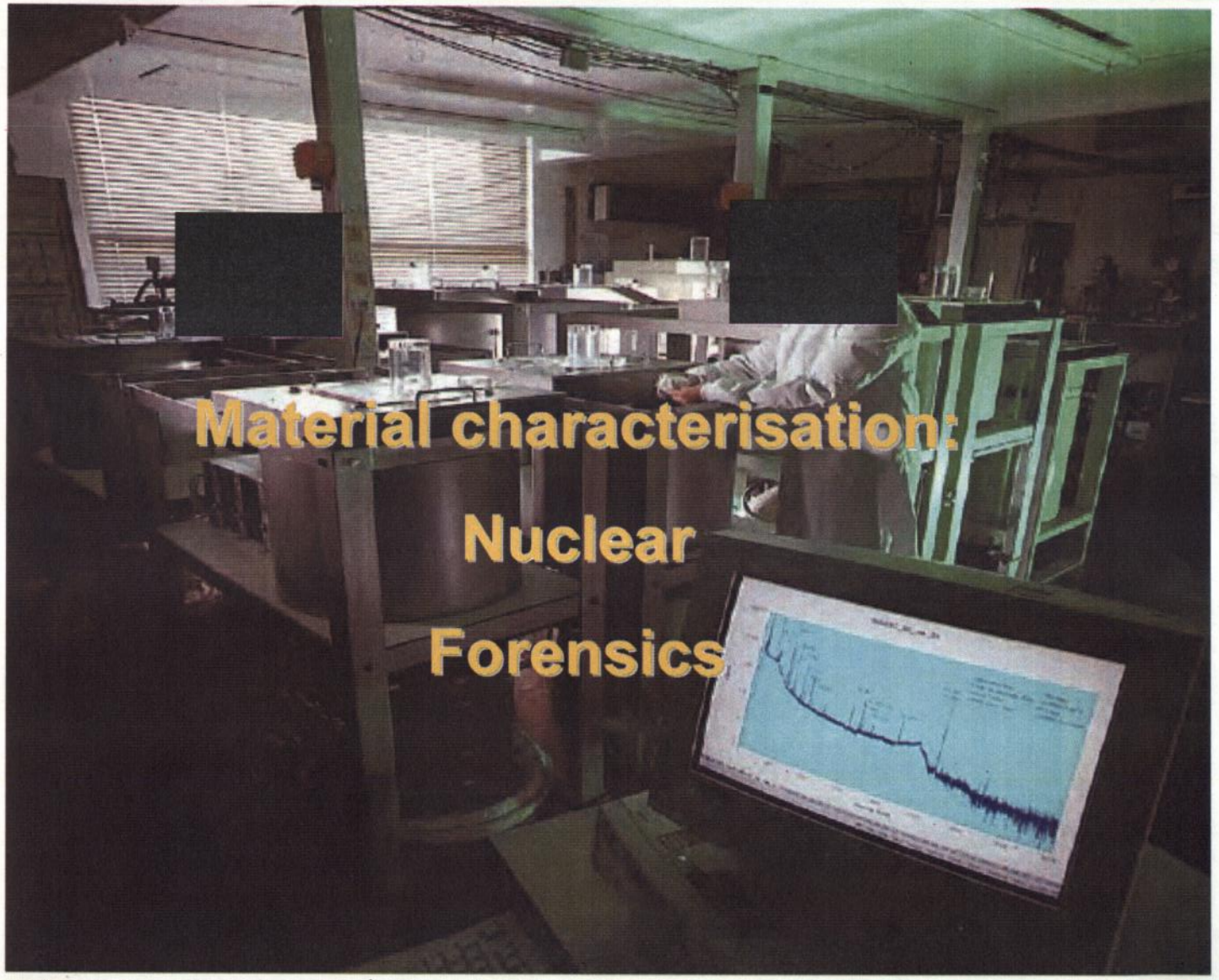
Courtesy of University College London



- Resistive plate chambers






Material characterisation:
Nuclear
Forensics

Characterisation : Radiological and Nuclear Forensics

Diverse range of radiological / nuclear (RN) materials could require forensic assessment:

Independent of the scenario, the same critical questions will be asked…

What is it? Where is it from? Who is involved? Where has it been?

Forensic & Attribution requirements

Quickly and efficiently characterise RN material

- Understand threat
- Develop response
- Device re-engineering
- Attribution chain

Quickly and efficiently attribute material to:-

- Individuals
- Organisations
- Suppliers
- States

Chain of custody & evidence management

- Collections
- Transportation
- Analysis
- Repositories & Waste

Objective: To provide end-to-end detection, recovery, characterisation and attribution from pre-/post-detonation scenarios using nuclear and conventional forensics.

Characterisation: Radiological and Nuclear Forensic

Developing an End-to-End Technical RNFA Capability






Collection → Characterisation → Discrimination → Disposal

- Provide guidance and collection capabilities to 1st response organisations on what to recover, how to recover it and how to package it for safe transit and efficient receipt.
- Cradle – to – grave ownership of recovered material
- Provide a robust chain of custody which governs the material flows from source, through analysis to disposal.

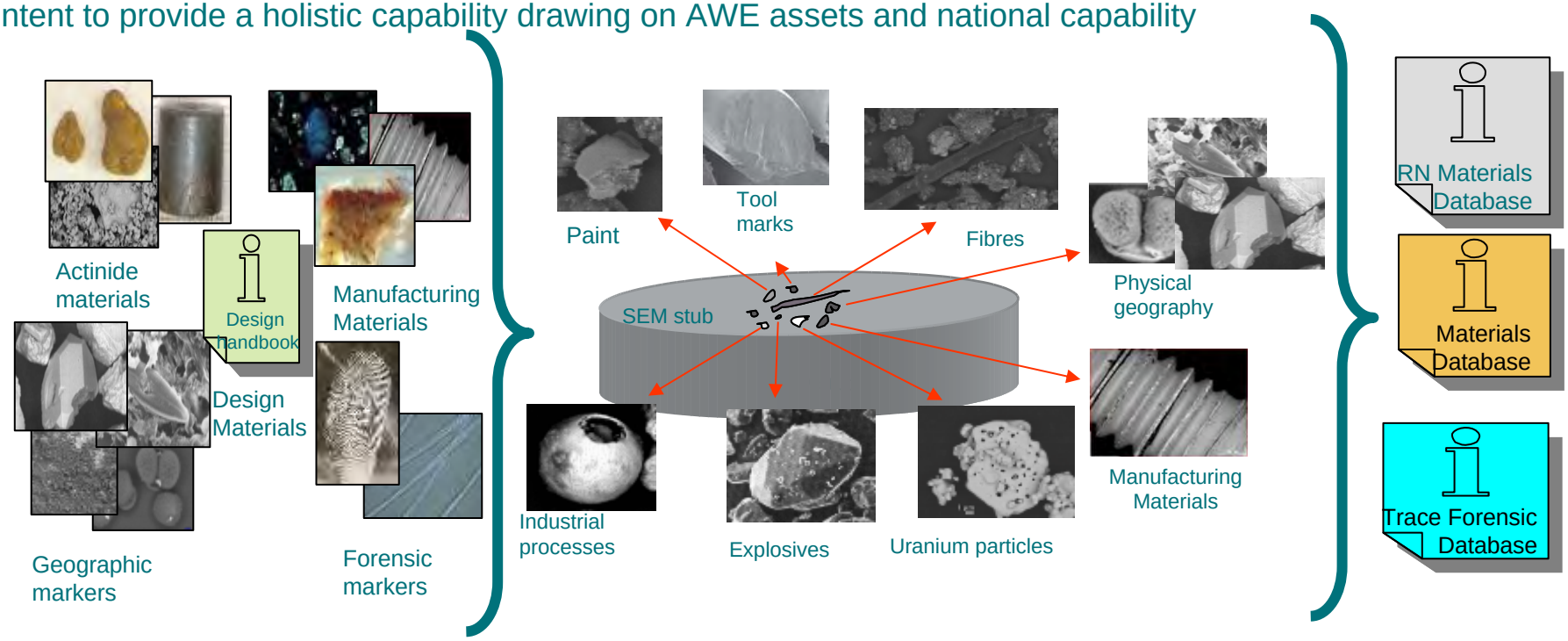
- Capability to recovery:
  - Interdicted materials / devices
  - Contaminated evidence
  - Post-detonation debris
- Characterisation & Attribution:
  - RN RadChem
  - Associated & trace materials
  - Yield determination
  - Materials origins & pathways history
  - Comparison with known data

Characterisation: Radiological and Nuclear Forensic

Exploitation and Geolocation

Working sponsors (HO, MoD) to develop capability to recover traditional forensic evidence for contaminated material (RNE) or RN material

Intent to provide a holistic capability drawing on AWE assets and national capability



Nuclear Forensics + Conventional Forensics = Total Forensic Exploitation

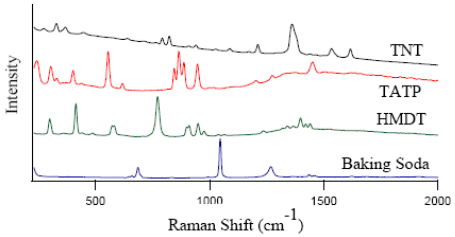
Characterisation: Field deployable capability

Search, detection and recovery SSoW

Mobile lab

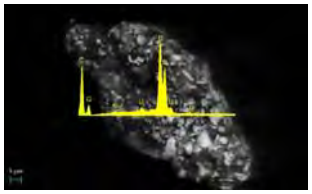
Mock-up of crime scene

(Images courtesy of AhuraScientific Inc)

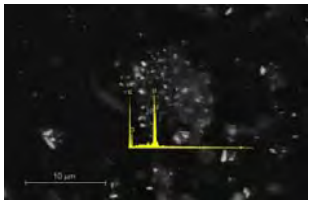


Explosive detection

(Image source: Hitachi High-Technologies Corp)



Traces of U found on gloves



Traces of U found on tooling

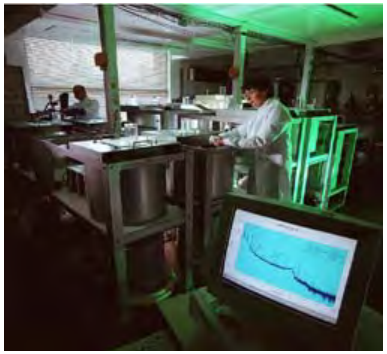
Characterisation: Laboratory capability

Sample preparation

HP Ge counting

Gross Alpha/Beta counters

SEM



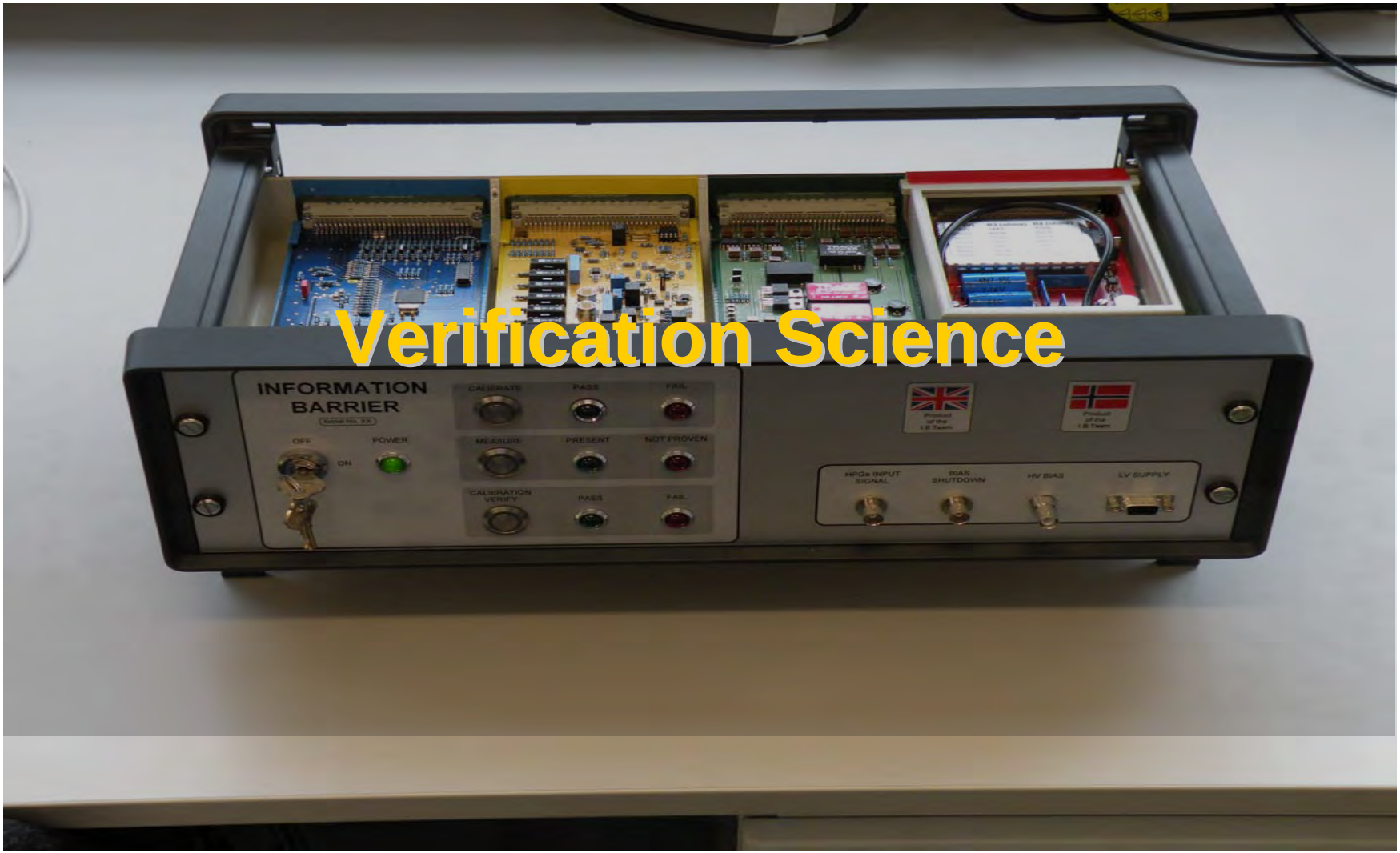
NaI coincidence detection

Ion chromotography

New glove boxes for contaminated evidence handling

Quemscan +automated particle recognition

SIM 1280


Verification Science
INFORMATION
BARRIER
OFF
ON
POWER
CALIBRATE
PASS
FAIL
MEASURE
PRESENT
NOT PROVEN
CALIBRATION
VERIFY
PASS
FAIL
HPGe INPUT
SIGNAL
BIAS
SHUTDOWN
HV BIAS
LV SUPPLY

Support to the CTBT

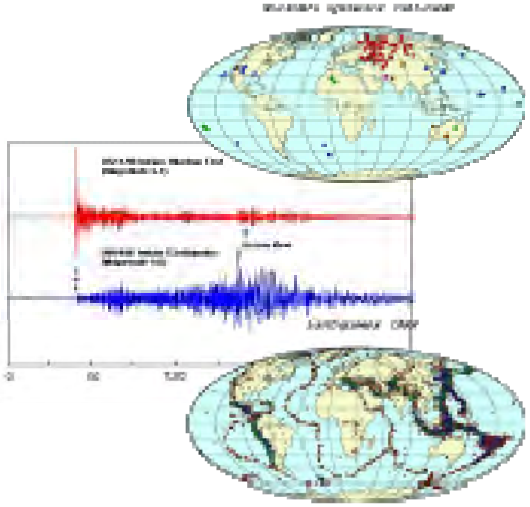
- To support the United Kingdom (UK) government in its obligations to the Comprehensive Test Ban Treaty
- To ensure facilities expected or required under UK treaty obligations to the CTBT are operated to the required standards
- To maintain a sustainable capability in CTBT verification technologies, including: Seismology, Infrasound, Hydroacoustics, Radionuclides, Radioactive Noble Gases, and On-Site Inspection (OSI)

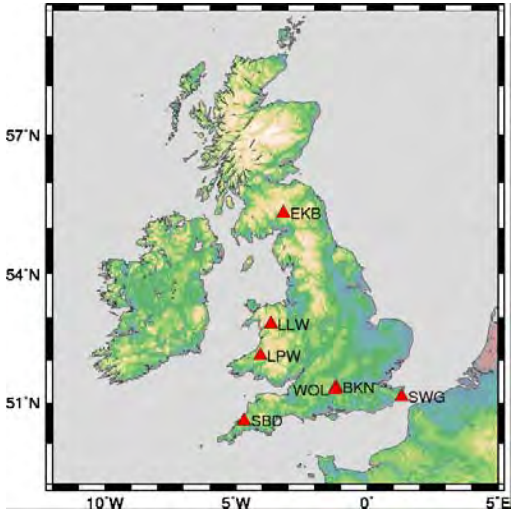
AWE and the CTBT

- Two key parts of the CTBT organisation are:
  - the International Data Centre (IDC) in Vienna,
  - the International Monitoring System (IMS) network of stations world-wide.
- AWE has responsibility for the UK's National Data Centre for the CTBT since July 2003
- AWE hosts a Radiochemistry laboratory (certified December 2004) GBL15
- AWE is also responsible for the operation of the Eskdalemuir seismometer array EKA
- Provision of technical experts to Working Group B

National Data Centre

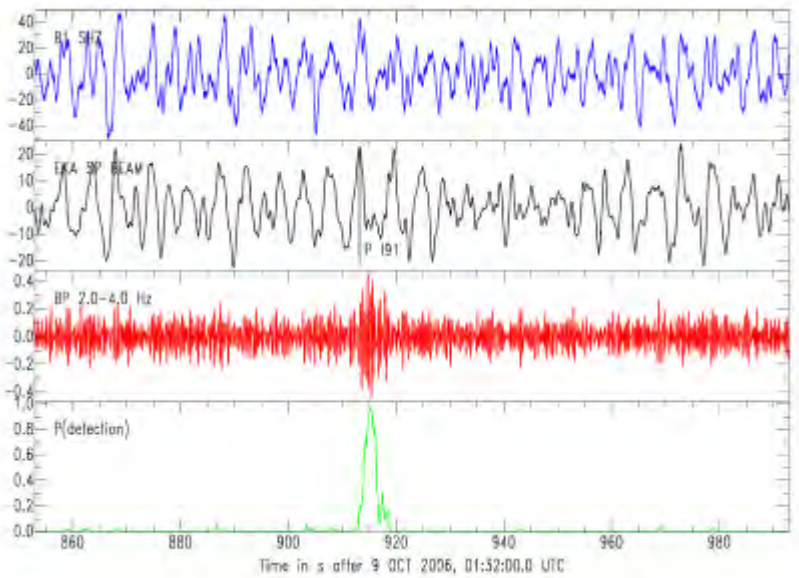
- Blacknest - UK National Data Centre at ‘centre of forensic seismology excellence’ for some 50 yrs
- Independent UK Seismic network
- Infrasound Array
- Historical seismic data archive from 1961
- Continuous recording of UK IMS data and other IMS data on request
- On-line data server to UK academic community





Forensic Seismology

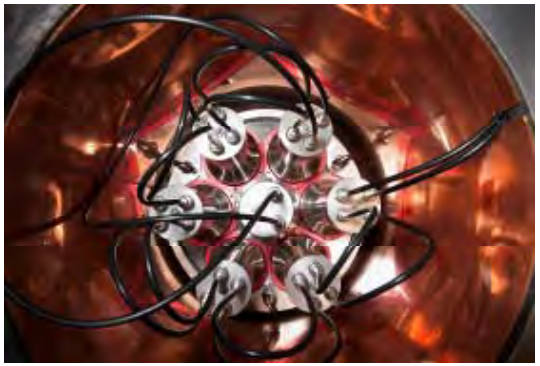
- Special event analysis
- Seismic research in collaboration with academia
- Currently supervising 3 PhD studentships Cambridge, Bristol and Leeds Universities
- Current major topics:
  - Earthquake source mechanism and depth analysis
  - Infrasound research
  - Improving CTBTO automated explosion criteria

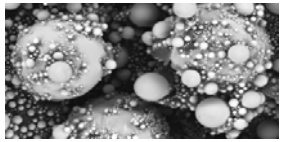


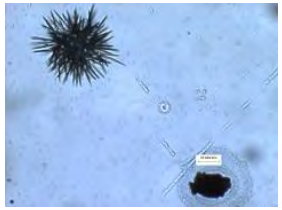
Signal at EKA Oct 06 DPRK test

Radiochemistry

- Certified Radionuclide Laboratory development
- Contribution to IAEA safeguards programme
- EngD student - Surrey
  - Cosmic veto system development
- Analysis and development for the CTBTO
  - Compton suppressed Gamma Spectrometry
- International Noble Gas Experiment
  - Currently purchasing a SAUNA Xe monitoring and analysis system







On Site Inspections

- Equipment in kind – Mobile field laboratory for IFE08 and 14
- On Site Inspectors – CTBTO training cycles
- Technical advice to CTBT
  - Expert attendance at Workshops
  - Field exercises (incl. equipment)
  - OSI manual

Arms Control Verification

UKNi
UNITED KINGDOM – NORWAY
INITIATIVE

- Nuclear Arms Control technical advice in support of the UK Government's policy.
- Develop methodologies and technologies to verify possible future nuclear disarmament treaties, and in partial fulfillment of the UK's commitments under the Non-Proliferation Treaty (NPT) article VI.
- Creating scenarios for exploring issues related to nuclear arms control and verification, without the risk of proliferation (NPT Articles I and II)
- Promoting understanding between Nuclear Weapon State and Non Nuclear Weapon State on issues faced by the other party
- Promoting discussions on how a NNWS should participate in a nuclear dismantlement verification process

UKNI History

2005 Review Conference: UK offer to work with other countries)

2006 UK/Norway initial contact

2007 Commenced two areas of Research:

- Information Barrier System and Managed Access
- Began development of technology, exercise infrastructure, inspection procedures and associated documentation

2008 Managed Access : Familiarisation Visit Exercise (Presented at 2009 Prep Comm)

2009 Information Barrier System:

- Two prototypes of the Information Barrier system were built, one in the UK and one in Norway, based on a jointly agreed design

2009 Managed Access: Monitoring Visit Exercise (Presented at 2010 Rev Con)

2010 Information Barrier System: Second jointly agreed system successfully built and trialled

2010 Managed Access: Focused Exercise (impact of Host security on Inspection activities)

2011 Workshop for NNWS on the UKNI: Hosted in London 7-9th December

2012 Future

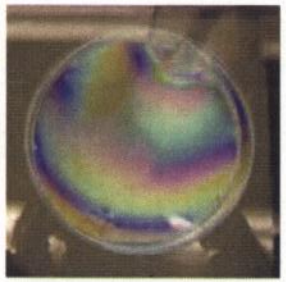
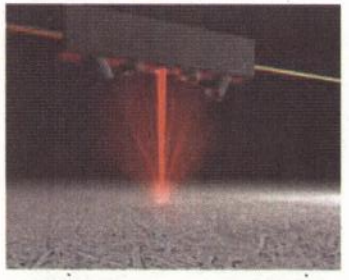
- UK Hosted P5 meeting on the UKNI April 4th
- Trial of Third Information barrier for Plutonium
- Development of Inspection procedures with focused exercises
- Continued engagement with International Community

Arms Control Verification Research

- Focus is on:
  - Verification of nuclear weapon dismantlement
  - Monitored storage of weapons and fissile components
  - Protection of classified and proliferative information during inspections
- Consideration of role as both:
  - The disarming (host) party
  - The inspecting party
- Investigating technical ways to verify nuclear dismantlement
- Understanding the Inspection Process
  - Uncleared visitors in sensitive facilities
  - Design exercises to explore possible approaches
- Joint Technology Development
  - Building Host and Inspector confidence
  - Mutually trusted equipment

Research in four technology domains:

- Managed Access
  - How to get Inspectors into sensitive nuclear facilities
- Non-Destructive Assay
  - Verify the presence of a warhead or fissile component in a container while protecting sensitive information
- Equipment Authentication
  - Verify that inspection equipment performs the intended function and nothing else
- Chain-of-Custody
  - Ensure neither host nor inspector can divert or tamper with Treaty-Accountable Items and authenticated equipment during warhead dismantlement and storage

Summary

AWE provides a unique contribution to the security of the United Kingdom, providing expert advice, technical solutions and support to Governments' national and international emergency response contingency plans.