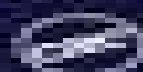


Second Edition

A large, billowing mushroom cloud from a nuclear explosion, with a bright orange and yellow core at the base, set against a clear blue sky.

# NUCLEAR FORENSIC ANALYSIS

Kenton J. Moody • Patrick M. Grant  
Ian D. Hutchison



CRC Press  
Taylor & Francis Group

# Nuclear Forensic Analysis

**NATO Advanced Research Workshop  
on Defence Against Weapons of Mass  
Destruction Terrorism**

## **Nuclear Forensic Analysis:**

**Nuclear Forensic Analysis** Kenton J. Moody, Patrick M. Grant, Ian D. Hutcheon, 2005-02-28 This book provides a primary reference source for nuclear forensic science including the vastly disciplinary nature of the overall endeavor for questioned weapons of mass destruction specimens Nothing like this exists even in the classified material For the first time the fundamental principles of radioforensic analysis all pertinent protocols and procedures computer modeling development interpretational insights and attribution considerations are consolidated into one convenient source The principles and techniques so developed are then demonstrated and discussed in their applications to real world investigations and casework conducted over the past several years Nuclear Forensic Analysis, Second Edition Kenton J. Moody, Patrick M. Grant, Ian D. Hutcheon, 2014-12-10 Now in its second edition Nuclear Forensic Analysis provides a multidisciplinary reference for forensic scientists analytical and nuclear chemists and nuclear physicists in one convenient source The authors focus particularly on the chemical physical and nuclear aspects associated with the production or interrogation of a radioactive sample They consolidate fundamental principles of nuclear forensic analysis all pertinent protocols and procedures computer modeling development interpretational insights and attribution considerations The principles and techniques detailed are then demonstrated and discussed in their applications to real world investigations and casework conducted over the past several years Highlights of the Second Edition include A new section on sample analysis considerations and interpretation following a post detonation nuclear forensic collection New case studies including the most wide ranging and multidisciplinary nuclear forensic investigation conducted by Lawrence Livermore National Laboratory to date Expanded treatments of radiologic dispersal devices RDDs and statistical analysis methodologies The material is presented with minimal mathematical formality using consistent terminology with limited jargon making it a reliable accessible reference The broad based coverage provides important insight into the multifaceted changes facing this recently developed science

**The New Nuclear Forensics** Vitaly Fedchenko, 2015 Nuclear material changes its form and properties as it moves through the nuclear fuel cycle from one facility to another Each step of the fuel cycle or each use of the material will inevitably leave its mark The science of determining the history of a sample of nuclear material through the study of these characteristics is known as nuclear forensics While nuclear forensic analysis has normally been associated with investigations and prosecutions in the context of trafficking of nuclear materials or nuclear terrorism it had wider applications in national security contexts such as nuclear non proliferation disarmament and arms control The New Nuclear Forensics is the first book to give a definitive guide to this broader definition of nuclear forensic analysis This book describes the various methods used in nuclear forensics giving first a broad introduction to the process followed by details of relevant measurement techniques and procedures In each case the advantages and limitations are outlined To put these methods in context the book also recounts the history of the discipline and describes the diverse contemporary applications of nuclear

forensics      *Application of Nuclear Forensics in Combating Illicit Trafficking of Nuclear and Other Radioactive Material* International Atomic Energy Agency,2013-06-30 This publication presents the outcome of an IAEA coordinated research project CRP which served as a technical forum for sharing international experiences in the field of nuclear forensics with a focus on improved procedures and techniques optimization of nuclear forensic analysis preservation of evidence and provision of support to Member States The CRP results address both technical needs to develop the discipline of nuclear forensics as well as to promote confidence in the application of analytical methods and understanding of the nuclear fuel cycle applied to nuclear forensics Topics include instrumentation and field work for evidence collection novel laboratory methods supporting a nuclear forensic examination and modeling for interpretation of nuclear forensic results

**Establishing a Nuclear Forensic Capability: Application of Analytical Techniques** International Atomic Energy Agency,2023-06-15 Nuclear forensics supports national nuclear security measures and criminal investigations by providing information on the identity origin and history of nuclear or other radioactive material found out of regulatory control This publication provides information for States on the use of nuclear forensics in response to criminal or other unauthorized acts involving nuclear or other radioactive material based on the guidance provided in IAEA Nuclear Security Series No 2 G Rev 1 Nuclear Forensics in Support of Investigations It is intended for technical and non technical personnel responsible for developing nuclear forensic analytical capabilities within the context of a broader national nuclear forensic programme stemming from national legislation It provides technical information that describes the application of specific methods analytical techniques and technical expertise used for nuclear forensic analysis in support of investigations of criminal or other unauthorized acts involving nuclear or other radioactive material      **NUCLEAR FORENSICS ANALYSIS CENTER**

**FORENSIC ANALYSIS TO DATA INTERPRETATION.** ,2011 The Nuclear Forensics Analysis Center NFAC is part of Savannah River National Laboratory SRNL and is one of only two USG National Laboratories accredited to perform nuclear forensic analyses to the requirements of ISO 17025 SRNL NFAC is capable of analyzing nuclear and radiological samples from bulk material to ultra trace samples NFAC provides analytical support to the FBI s Radiological Evidence Examination Facility REEF which is located within SRNL REEF gives the FBI the capability to perform traditional forensics on material that is radiological and or is contaminated SRNL is engaged in research and development efforts to improve the USG technical nuclear forensics capabilities Research includes improving predictive signatures and developing a database containing comparative samples      **Handbook of Radioactivity Analysis** Michael F. L'Annunziata,2012-08-16

Authoritative reference providing the principles practical techniques and procedures for the accurate measurement of radioactivity      *Educational Programme in Nuclear Security* International Atomic Energy Agency,2010 Higher education plays an essential role in nuclear security capacity building It ensures the availability of experts able to provide the necessary competencies for effective national nuclear security oversight of nuclear and other radioactive material and to establish and

maintain an appropriate nuclear regime in a State This guide presents both the theoretical knowledge and the practical skills necessary to meet the requirements described in the international framework for nuclear security Emphasis is placed on the implementation of these requirements and recommendations in States On the basis of this guide a university should be able to develop its own academic programme tailored to suit State specific educational needs in the area of nuclear security and to meet national requirements

**The U.S. National Nuclear Forensics Library, Nuclear Materials Information Program, and Data Dictionary**, 2011 Nuclear forensics assessments to determine material process history requires careful comparison of sample data to both measured and modeled nuclear material characteristics Developing centralized databases or nuclear forensics libraries to house this information is an important step to ensure all relevant data will be available for comparison during a nuclear forensics analysis and help expedite the assessment of material history The approach most widely accepted by the international community at this time is the implementation of National Nuclear Forensics libraries which would be developed and maintained by individual nations This is an attractive alternative to an international database since it provides an understanding that each country has data on materials produced and stored within their borders but eliminates the need to reveal any proprietary or sensitive information to other nations To support the concept of National Nuclear Forensics libraries the United States Department of Energy has developed a model library based on a data dictionary or set of parameters designed to capture all nuclear forensic relevant information about a nuclear material Specifically information includes material identification collection background and current location analytical laboratories where measurements were made material packaging and container descriptions physical characteristics including mass and dimensions chemical and isotopic characteristics particle morphology or metallurgical properties process history including facilities and measurement quality assurance information While not necessarily required it may also be valuable to store modeled data sets including reactor burn up or enrichment cascade data for comparison It is fully expected that only a subset of this information is available or relevant to many materials and much of the data populating a National Nuclear Forensics library would be process analytical or material accountability measurement data as opposed to a complete forensic analysis of each material in the library

**Nuclear Forensics Support** International Atomic Energy Agency, 2006 Illicit trafficking of nuclear and other radioactive material has been an issue of concern since the first seizures in the early 1990s By the end of 2004 IAEA member states had confirmed 540 cases with another 500 unconfirmed This publication sets out information on the use of nuclear forensic investigation methods in incidents involving nuclear and other radioactive material Issues covered include definitions of key terms the Nuclear Forensics Plan of Action incident response laboratory sampling and distribution nuclear forensic analysis traditional methods of forensic analysis nuclear forensic interpretation and the procedures involved in requesting assistance from the IAEA

**Defence Against Weapons of Mass Destruction Terrorism** NATO Advanced Research Workshop on Defence Against Weapons of Mass Destruction Terrorism, 2009-06-26 In Defence Against Weapons of

Mass Destruction Terrorism the editors examined the class of Weapons of Mass Destruction WMD for terrorist use and have found that their effects range from serious nuisance value up to catastrophic destruction of a large urban area There are some differences in the effects depending on whether they are used against military or civilian targets whether they are used from inside the target area or outside and between those weapons for which MOPP Mission Oriented Protective Posture gear can provide useful protection Biological Weapons Chemical Weapons and those for which it often cannot radiation nuclear explosions These are useful ways to begin thinking about establishing protocols for protecting our armed forces and the civilian population they are sworn to defend

Trace Analytical Techniques for Nuclear Forensics ,1999 Over the history of the Savannah River Site the Savannah River Technology Center SRTC has developed high sensitivity analytical capabilities in support of the Site's Environmental Monitoring Program and nuclear material protection process Many of these techniques are applicable to the developing need for nuclear forensic analysis capabilities Radiological and critically control procedures are in place at the SRTC as well as clean room practices to minimize the potential for a radiological evidentiary sample to contaminate personnel and the facility as well as to minimize contaminating the sample thus rendering it useless by law enforcement agencies Some of the trace analytical techniques available at the SRTC include ultra low level gamma and alpha spectrometry high sensitivity thermal ionization mass spectrometry time of flight secondary ion mass spectrometry and trace organic analyses These techniques have been tested during a planned domestic smuggling exercise and in the analysis of an unknown sample In the event of an interdiction involving the illegal use or movement of radioactive material by U S law enforcement agencies local state or federal forensic analyses will be used in developing and building a legal case against the perpetrators The Savannah River Technology Center SRTC at the U S Department of Energy's Savannah River Site a former nuclear production site currently conducting nuclear material stabilization missions located in Aiken South Carolina has a long history of performing trace analytical analyses for environmental monitoring Many of these techniques are also applicable to nuclear forensic analyses A summary of the trace analytical techniques used at the SRTC which are applicable to Nuclear Forensics is presented in this paper Contamination control of facilities and personnel involved in the analytical analyses as well as preventing contamination of the sample is a unique challenge for nuclear forensic analyses A discussion of sample handling and contamination control procedures is included in this paper Some of the applicable analytical techniques available at the SRTC for nuclear forensic analyses include ultra low level gamma and alpha spectroscopy high sensitivity thermal ionization mass spectrometry TIMS time of flight secondary ion mass spectrometry TOF SIMS and trace organic analyses Results from analyses of special nuclear material SNM standards materials from nuclear smuggling exercises and materials of unknown origin will be presented

Image Analysis in Nuclear Forensics ,2015 In this technical report a new approach for characterising powder of uranium ore concentrates UOCs is presented It is based on image texture analysis and multivariate data modelling Twenty six different UOC samples were evaluated applying the angle

measure technique AMT algorithm to extract textural features on samples images acquired at 250 and 1 000 magnification by scanning electron microscope SEM At both magnifications this method proved effective to classify the different types of UOC powder based on the surface characteristics that depend on particle size homogeneity and graininess and are related to the composition and processes used in the production facilities Using the outcome data from the application of the AMT algorithm the total explained variance was higher than 90 % with principal component analysis PCA This preliminary study shows that this method is able to distinguish samples with similar composition but obtained from different facilities The mean angle spectral data obtained by the image texture analysis using the AMT algorithm can be considered as a specific fingerprint or signature of UOCs and could be used for nuclear forensic investigation Image Analysis in Nuclear Forensics ,2016 In this technical report a new approach for characterising powder of uranium ore concentrates UOCs is presented It is based on image texture analysis and multivariate data modelling Twenty six different UOC samples were evaluated applying the angle measure technique AMT algorithm to extract textural features on samples images acquired at 250 and 1 000 magnification by scanning electron microscope SEM At both magnifications this method proved effective to classify the different types of UOC powder based on the surface characteristics that depend on particle size homogeneity and graininess and are related to the composition and processes used in the production facilities Using the outcome data from the application of the AMT algorithm the total explained variance was higher than 90 % with principal component analysis PCA This preliminary study shows that this method is able to distinguish samples with similar composition but obtained from different facilities The mean angle spectral data obtained by the image texture analysis using the AMT algorithm can be considered as a specific fingerprint or signature of UOCs and could be used for nuclear forensic investigation SIPRI Yearbook 2008 Stockholm International Peace Research Institute,2008 The 39th edition of the SIPRI Yearbook analyses developments in 2007 in Security and conflicts Military spending and armaments Non proliferation arms control and disarmament The SIPRI Yearbook contains extensive annexes on the implementation of arms control and disarmament agreements and a chronology of events during the year in the area of security and arms control **Forensic Science Review** ,2003 *Dynamic Analysis Environment for Nuclear Forensic Analyses* ,2015 *Nuclear Forensics* Division on Earth and Life Studies,Nuclear and Radiation Studies Board,2010-07-29 Nuclear forensics is important to our national security Actions including provision of appropriate funding are needed now to sustain and improve the nation s nuclear forensics capabilities The Department of Homeland Security DHS working with cooperating agencies and national laboratories should plan and implement a sustainable effective nuclear forensics program Nuclear forensics is the examination and evaluation of discovered or seized nuclear materials and devices or in cases of nuclear explosions or radiological dispersals of detonation signals and post detonation debris Nuclear forensic evidence helps law enforcement and intelligence agencies work toward preventing mitigating and attributing a nuclear or radiological incident This report

requested by DHS the National Nuclear Security Administration and the Department of Defense makes recommendations on how to sustain and improve U S nuclear forensics capabilities The United States has developed a nuclear forensics capability that has been demonstrated in real world incidents of interdicted materials and in exercises of actions required after a nuclear detonation The committee however has concerns about the program and finds that without strong leadership careful planning and additional funds these capabilities will decline

**Application of Modern Autoradiography to Nuclear Forensic Analysis** ,2018      Nuclear Forensic Inferences Using Iterative Multidimensional Statistics ,2009

Nuclear forensics involves the analysis of interdicted nuclear material for specific material characteristics referred to as signatures that imply specific geographical locations production processes culprit intentions etc Predictive signatures rely on expert knowledge of physics chemistry and engineering to develop inferences from these material characteristics Comparative signatures on the other hand rely on comparison of the material characteristics of the interdicted sample the questioned sample in FBI parlance with those of a set of known samples In the ideal case the set of known samples would be a comprehensive nuclear forensics database a database which does not currently exist In fact our ability to analyze interdicted samples and produce an extensive list of precise materials characteristics far exceeds our ability to interpret the results Therefore as we seek to develop the extensive databases necessary for nuclear forensics we must also develop the methods necessary to produce the necessary inferences from comparison of our analytical results with these large multidimensional sets of data In the work reported here we used a large multidimensional dataset of results from quality control analyses of uranium ore concentrate UOC sometimes called yellowcake We have found that traditional multidimensional techniques such as principal components analysis PCA are especially useful for understanding such datasets and drawing relevant conclusions In particular we have developed an iterative partial least squares discriminant analysis PLS DA procedure that has proven especially adept at identifying the production location of unknown UOC samples By removing classes which fell far outside the initial decision boundary and then rebuilding the PLS DA model we have consistently produced better and more definitive attributions than with a single pass classification approach Performance of the iterative PLS DA method compared favorably to that of classification and regression tree CART and k nearest neighbor KNN algorithms with the best combination of accuracy and robustness as tested by classifying samples measured independently in our laboratories against the vendor QC based reference set



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16 3 2 4 3 cm 2 note that we should remember that  $\sin 60^\circ$