COMMENTARY

PREPARING FOR THE WORST

An international data bank of nuclear explosives is needed to determine the source of nuclear materials following an explosion, argue **Michael May**, **Jay Davis** and **Raymond Jeanloz**.

How soon after an attack could the source of a nuclear explosive be determined?

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The ultimate terrorist attack is a nuclear explosion in a city. The likelihood of such an event is uncertain, but the consequences would be enormous. As many as a hundred thousand people could be killed, and many more left wounded or sick; several square miles of the city would be destroyed or contaminated, and the political and social consequences would be far-reaching.

Once it had happened, there would be an urgent need to determine where the nuclear explosive came from and who was responsible, and not just for retribution: a pressing concern would be to assess the chances of another nuclear detonation. We propose an international data bank of known nuclear explosive materials to aid in that process.

We also argue that once it becomes possible to trace nuclear explosives, this could in itself deter the criminal transfer of such materials from governments to terrorists. Although subnational groups may be able to assemble a nuclear device surreptitiously, they do not have the facilities to make weapons-grade nuclear materials[1]. Terrorists must therefore buy or steal what they need.

Most nuclear explosive materials are in the former Soviet Union and the United States, along with far smaller amounts in other countries, including Pakistan and North Korea. It is feared that significant quantities of nuclear weapons materials may be kept under poor security[2]. Because the manufacture and storage of such materials are under state control, the knowledge that significant capabilities exist for attribution should encourage better security and accounting.

similar to what we propose. But some of these are held privately, for example at the Institute for Transuranium Elements (ITU) in Karlsruhe, Germany, or by individual governments. Even the international database held by the International Atomic Energy Agency (IAEA) in Vienna, Austria, is incomplete and not designed for the event-driven rapid forensics that would be required in response to a terrorist detonation. They therefore provide limited deterrence[3].

An international data bank of the type we are suggesting would include a database (containing classified and non-classified information), a physical library of nuclear explosive materials, and vetted procedures for handling both data and samples. Cooperation of governments will be central to its success, and once the data bank is established, refusing to provide samples would focus suspicion.

> **"Exclusion of certain sources can be as important as full attribution during the period of political uncertainty after an attack."**

How quickly can nuclear material be identified in practice? Even after a nuclear explosion most of the nuclear material — plutonium or highly enriched uranium — remains intact, as only a fraction gets converted into energy and fission products. Much of the other material in the weapon is also left behind, usually in a highly irradiated state. Although explo-

fragments, its radioactivity makes it detectable, identifiable and collectable, and a wealth of information can be obtained from its analysis: the efficiency of the explosion, the materials used and, most important for our purpose, some indication of where the nuclear material came from (see Table).

Detective work

What clues would such analysis rely on? Uranium isotopes, for example, vary in composition and impurities according to where the uranium was mined, and how it was processed[4]. Weapons-grade plutonium can be exposed during its production to different neutron fluxes and energies, depending on the particular reactor used. It is also possible to detect the length of time plutonium has spent in the reactor. Such information may not point to a single origin, let alone determine the full chain of transfer from source to terrorist group. Still, exclusion of certain sources can be as important as full attribution during the period of political uncertainty after an attack, and is usually more feasible.

An adequate data bank would consist of three components: a database that lists key chemical (elemental and isotopic) and physical properties of known plutonium and highly enriched uranium samples; a suite of samples or access to representative samples of these nuclear explosive materials; and validated procedures for performing the analyses and for handling the samples and information in the database. The database would collect best-estimate values and uncertainties for all measurements.

suspicion of political bias by conducting chemical and physical analyses in several laboratories in different countries under the international auspices of a body such as the IAEA. Such transparency is crucial both when the database is set up and during forensics activity after an attack.

A key technical issue is establishing validated methods for performing analyses or for handling the samples, and is being partially addressed by the Nuclear Smuggling International Technical Working Group at the ITU. This group of international experts is developing mutually agreed-upon techniques for performing reliable nuclear forensics, which are then peer-reviewed and regularly benchmarked in tests using unfamiliar samples[4].

Access to physical samples is needed to validate the database, and to allow more detailed analyses in the event of a nuclear detonation. The best approach would be to archive gram or subgram quantities of representative material under the control of an international body such as the IAEA. But this may not always be possible because of concerns over sensitive military or commercial secrets — concerns that are codified in law in some states.

Secrets that could be revealed by the sort of database described here include reactor-fuel production technologies that may have economic value in the eyes of the fuel producer. Consequently, the database would probably need to have both public and classified parts. Because this could threaten confidence in the database, we advocate establishing as much transparency as possible ahead of time, in procedures as well as data.

For the public part of the database, it should be technically possible to include key information — such as the isotopic composition of source materials — that does not reveal details of how the weapons are made. Questions may arise regarding the reliability of the database, including whether fake samples may be submitted (spoofing). We believe that fakes would be open to discovery through subsequent analyses. But such questions must be addressed and resolved, at least among partners in the database, for an attribution decision to be generally credible and accepted.

Stopping illegal transfers of uranium or plutonium

Nuclear forensic activities following a terrorist explosion

Action	Timescale	Methods and limitations
Determination that detonation is nuclear	Less than an hour	Determined from yield (seismic magnitude), optical signature and presence of excess radiation above normal background (due to neutron activation and presence of fallout). Rapid classification as unambiguously nuclear can be more challenging for low yields (sub-kiloton)
Identification of fuel type and sophistication of device, and initial assessment of isotopic signatures	Hours to weeks	Limited by time needed to collect sample, bring to laboratory and prepare for adequate analysis
Complete characterization of chemical and physical signature	1 to 2 weeks	Limited by decay rates of isotopes and by need for multiple high-resolution analyses
Attribution and assessment of further threat	Hours to years	Limited by availability of relevant data bank

There is precedent for dealing with such issues in treaty-verification regimes, which often involve a mix of public and classified methods. One approach we advocate is to allow some of the database to remain classified, but in such a way that it can be interrogated at a time of need by, for example, a group of pre-approved analysts selected from participating countries.

Secret codes

In cases when sample materials are deemed too sensitive to be provided to an international archive, procedures similar to the 'challenge inspections' agreed on by signatories to arms-control agreements could be used. Challenge inspections of weapons facilities can be requested by the international inspectorate for the Chemical Weapons Convention, for example. The right to challenge inspections was embodied in the most recent IAEA protocol for inspecting nuclear-energy sites (the so-called Additional Protocol) but has not been agreed to by all parties to the Nuclear Non-Proliferation Treaty. However, such inspections could be used to make samples available under appropriate and pre-approved conditions — notably, in response to a terrorist nuclear detonation.

For the classified part of the database, there would be information protocols that allow appropriate disclosure of sensitive data (perhaps to a small set of vetted analysts) in times of need. We recommend using 'message digests' (or 'hashing') to encapsulate analytical information and to interrogate the database[1]. Hashing is often used in electronic commerce to keep information secure. The advantage of hashing is that only a small fraction of the data file is encrypted and transmitted, so it is less vulnerable to inappropriately revealing sensitive information than encrypting alone. And provided that information in the secure database is stored in a predetermined format, the task of comparing it to new forensic information is straightforward.

A primary motivation for disclosure of information to this data bank, and for participation in the associated forensic analysis in attribution decisions and the consequent political or military steps. Although cooperation in a data bank is not spelled out as a requirement in the Nuclear Non-Proliferation Treaty, cooperation could be mandated for states receiving nuclear-related exports from members of the Nuclear Suppliers Group, as occurred when the Additional Protocol was introduced. Alternatively, cooperation could be mandated by a United Nations Security Council resolution.

A key feature of the nuclear forensics timeline (see Table) is that analytical information can be available both before a detonation — if smuggled nuclear materials are intercepted, for example — and within hours after a terrorist nuclear detonation. But attribution will require an appropriate database for interpreting the forensics information. In the current situation, obtaining this information could require months or longer after a detonation, yet there would be great pressure for rapid, actionable information, including ruling out potential sources. Establishing the data bank proposed here would greatly reduce the time between this most terrible of events and the ability to respond to it. ■

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