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US-Russian Collaboration in Nuclear Forensics - INMM 2011

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US-Russian Collaboration in Nuclear Forensics

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ABSTRACT

Arguably, there can be no greater collaboration in the new science of nuclear forensics than that between the world's two largest nuclear powers, the United States and the Russian Federation (RF). There has been limited engagement in the past. For example, from 2004 through 2006, LLNL and the Bochvar Institute (VNIINM) cooperated on the further analysis of an HEU sample interdicted in Rousse, Bulgaria, in 1999. In 2004, LLNL also began a collaboration with the Russian Institute of Technical Physics (VNIITF) on the identifying characteristics of research reactor fuel, which led, in turn, to the current collaboration on concepts for the development of a bilateral nuclear forensics database for research reactor fuel. Nevertheless, greater collaboration between the US and RF on nuclear forensics is desirable. Potentially fruitful areas of collaboration include improved methods of nuclear materials analysis, discovery of new signatures for nuclear materials, knowledge management & analysis techniques, and uncertainty/confidence articulation. Of course, there are significant obstacles to collaboration as well. First among these are security considerations, since nuclear forensics, by its very nature, often touches on sensitive or classified issues of fuel cycle or weapons technology. Funding for both the US and Russian laboratories can also be a problem in today's era of tighter budgets. Finally, an appropriate legal and policy framework for collaboration is required to engage in such technical (lab-to-institute) collaboration. However, both President Obama and President Medvedev have recognized the special responsibility of the United States and Russia for nuclear security and, through the 2010 Nuclear Security Summit Communique and Work Plan, have joined other countries in acknowledging the importance of bilateral and multilateral cooperation to develop national capacities in nuclear forensics.

INTERNATIONAL COLLABORATION IN NUCLEAR FORENSICS

International concern over illicit trafficking in nuclear material has certainly existed since the early 1990's, following 11 reported seizures of HEU or Pu in eastern and central Europe from 1992 through 1996.[1] In fact, the first organizational meeting of the Nuclear Forensics International Technical Working Group (ITWG) was held at LLNL in 1995, an organization whose sixteenth meeting was held this June in Kiev, the Ukraine. However, this initial concern was heightened considerably following the terrorist attacks of September 11, 2001. Since Al Qaeda had frequently expressed a desire to obtain weapons of mass destruction of all sorts, including nuclear weapons, one could only imagine what devastation it could wreak should it succeed in its efforts.

Nuclear security has been an important priority for both Presidents Bush and Obama in the United States, and Presidents Putin and Medvedev in the Russian Federation. For example, on

[1] International Atomic Energy Agency, IAEA Illicit Trafficking Database, http://www-ns.iaea.org/security/itdb.asp; accessed May 26, 2010.

July 16, 2006, Presidents Bush and Putin announced the formation of the Global Initiative to Combat Nuclear Terrorism (GICNT) and the U.S. and Russia continue to serve as co-chairs of the GICNT.[2] On April 12-13, 2010, President Obama hosted a Nuclear Security Summit in Washington, with the goal of enhancing international cooperation to prevent nuclear terrorism. Over 40 nations, including the Russian Federation, participated in the Summit. One of the key focus areas for the conference was the prevention of nuclear smuggling. In the Summit's Communiqué, the Participating States committed themselves to cooperation "in relevant areas such as nuclear detection, forensics, law enforcement, and the development of new technologies."[3] The accompanying work plan for the summit noted ongoing work in the area of nuclear forensics, while encourage states to "explore ways to work together to develop national capacities for nuclear forensics, such as the creation of national libraries and an international directory of points of contact, to facilitate and encourage cooperation between States in combating illicit nuclear trafficking." and "to enhance broader cooperation among local, national and international customs and law enforcement bodies to prevent illicit nuclear trafficking and acts of nuclear terrorism, including through joint exercises and sharing of best practices."[4]

IMPORTANCE OF US-RUSSIAN COLLABORATION IN NUCLEAR FORENSICS

Arguably, there can be no greater international collaboration in the new science of nuclear forensics than that between the world's two largest nuclear powers, the United States and the Russian Federation (RF). The U.S. and RF possess the two largest stockpiles of nuclear weapons by far, as well as the largest stockpiles of weapons-usable material in general. This implies that the nuclear forensic probabilities (the statistical probability that an interdicted material derived from a given source) for any sample, no matter what its materials characteristics, are influenced more by the size and characteristics of the U.S. and Russian material stockpiles than anything else.[5] In addition, the U.S. and Russian nuclear programs combined have more than a century of experience with nuclear materials-- in their production, in their analysis, and in their use. For the most part, these two nuclear programs have evolved independently, so there would seem to be ample opportunities for learning from each other. Fortunately, we have several previous collaborations on which to build this new partnership.

PREVIOUS COLLABORATIONS[6]

Analysis of an Interdicted HEU Sample (LLNL/VNIINM)

Lawrence Livermore National Laboratory (LLNL) and the Bochvar All-Russian Scientific Research Institute for Inorganic Materials (VNIINM) collaborated on the analysis of a highly

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[2] For more information about the Global Initiative to Combat Nuclear Terrorism, please see: http://www.state.gov/t/isn/c18406.htm; accessed May 26, 2010.

[3] Communiqué of the 2010 Nuclear Security Summit, http://www.state.gov/nuclearsummit/releases/140154.htm; accessed 5/26/10.

[4] Work Plan of the 2010 Nuclear Security Summit, http://www.whitehouse.gov/the-press-office/work-plan-washington-nuclear-security-summit ; accessed 5/26/10.

[5] M. Kristo, "Univariate Nuclear Forensic Signatures: A Theoretical Treatment," in preparation.

[6] M. Kristo, "U.S. and Russian Collaboration In the Area of Nuclear Forensics," paper published in "The Future of the Nuclear Security Environment in 2015," proceedings of the international workshop sponsored by the U.S. National Academy of Sciences and the Russian Academy of Sciences, November 12-13, 2007.

enriched uranium (HEU) sample from 2004 through 2006. Bulgarian customs officers interdicted the sample on May 29, 1999, transferring the sample to LLNL for analysis on February 24, 2000. The sample was analzyed by LLNL and Oak Ridge National Laboratory (ORNL), with Argonne National Laboratory (ANL) and Savannah River National Laboratory (SRNL) providing reactor modeling studies to support the nuclear forensic interpretation. These analyses confirmed that the material was HEU (~73% ^{235}U) from irradiated reactor fuel reprocessed around 1993.[7] Both nuclear and conventional forensic signatures suggested an origin in the former Soviet Union.

The U.S.-Russian Counter Terrorism Working Group sought to establish a model for real-time interaction between U.S. national laboratories and Russian institutes on a real nuclear forensics case, directing LLNL to provide a portion of the "Bulgarian" HEU sample to a Russian institute for nuclear forensic analysis, including confirming laboratory analyses, reactor modeling, and material identification. This project was considered to be a first step towards a new mechanism for sharing information and analysis relating to illicitly trafficked nuclear material. Accordingly, LLNL negotiated a contract with the Bochvar Institute, signed on July 8, 2004, for the analysis and interpretation of a 0.59 gram aliquot of the original sample. Because of the much smaller sample size, the Bochvar Institute was not able to perform as extensive a suite of analyses as LLNL and ORNL.

The Bochvar Institute confirmed the analytical results of the U.S. national laboratories. In addition, they found a minor, Al-containing phase in the sample not found in the U.S. analyses, a phase that could possibly be important in the attribution process. The Russians agreed with the key findings of the U.S. researchers: that the material was reprocessed HEU, that it was irradiated in a reactor to extremely high burn-up, and that it was probably being prepared for research reactor fuel. However, they did not agree with the attribution of the material to the former Soviet Union, but felt that this sample could not be attributed uniquely to any country, but could have been produced by any nuclear state possessing the appropriate processing facilities.

At the post-project meeting, both sides agreed on the following areas for future cooperation:

- better understanding of each other's methodologies and techniques
- improved data sets (databases)
- participation in nuclear forensic analytical round robins
- enlightening both country's policy makers on areas in which mutual cooperation is possible and areas in which mutual cooperation is not possible

Identifying Characteristics of Research Reactor Fuel (LLNL/VNIITF)

LLNL has been collaborating with the Federal State Unitary Enterprise-Russian Federal Nuclear Center, Academician Zababakhin Scientific Research Institute of Technical Physics (VNIITF), located in Snezhinsk, in the area of identifying characteristics of research reactor fuel for several years. Research reactor fuel is one of the most significant nuclear threats because the material is frequently HEU. In addition, many of the research reactors are pulse reactors that experience

[7] K. Moody, I. Hutcheon, and P. Grant, Nuclear Forensic Analysis (New York: Taylor & Francis, 2005), pp. 401-420.

very low burn-up, with the radioactivity in the fuel elements decaying very quickly after use. HEU parts from these pulse reactors can often be picked up by hand after only a few days without any adverse consequences. In addition, research reactors are frequently not protected at a level commensurate with the risk of diversion of a significant quantity of HEU.[8]

Our initial collaboration involved detailed analysis of 3 research reactor fuels. However, VNIITF had difficulty in obtaining export approval for the resulting data and eventually provided a report compiled from fuel design specifications and "binned" experimental data. After subsequent discussions with Rosatom, the researchers at VNIITF believe the development of parallel databases in the U.S. and R.F. is the most straightforward approach to solving security and export control considerations. This approach is fully in line with the evolving concept of distributed international nuclear forensic databases.[9]

Accordingly, VNIITF is currently executing a contract with LLNL, funded by the Department of Homeland Security/National Technical Nuclear Forensics Center. This contract was split into two stages. The first stage, which was recently completed, involved the following tasks:

1. Analysis of all R.F. and U.S. research reactors and selection of reactors for inclusion into the database. Description of unique features of fuel elements for several former Soviet reactors.
2. Development of the plan for loading the joint database with information on research reactor characteristics
3. Creation of the database structure using Microsoft Access.

LLNL recently approved the deliverables under Phase I and has authorized VNIITF to proceed with Phase II, which has the following tasks:

1. Selection of the basic software, creation of the database structure and interface, and development of the procedures to identify fuel samples and provide information analysis.
2. Step-by-step loading of the database with information on the characteristics of U.S. and R.F. research reactors.

We believe that the success of this project will lead to a larger effort that must necessarily involve the participation of multiple Russian institutes and U.S. national laboratories. It may also require high-level approval from the U.S. and/or Russian governments in order to populate the database with information about some of the more sensitive reactor designs.

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[8] P. Bleek and L. Holgate, "Minimizing Civil Highly Enriched Uranium Stocks by 2015: A Forward-Looking Assessment of U.S.-Russian Cooperation," paper published in "The Future of the Nuclear Security Environment in 2015," proceedings of the international workshop sponsored by the U.S. National Academy of Sciences and the Russian Academy of Sciences, November 12-13, 2007.

[9] Stephen LaMont, John Wacker, Michael Kristo, Michael Curry, and Marcia Brisson, "National Nuclear Forensics Libraries: A Suggested Approach for Country Specific Nuclear Material Databases," presented at the JAEA Workshop on Nuclear Forensics, October 5-6, 2010. http://www.jaea.go.jp/04/np/activity/2010-10-05/2010-10-05-20.pdf; accessed on May 27, 2010.

GENERAL AREAS OF COLLABORATION

Improved Methods of Analysis

Scientific analyses remain the primary source for nuclear forensic data. For the most part, improving methods of analysis is considered a purely scientific endeavor – with few, if any, security restrictions. Therefore, improving our methods of analysis might be an easy place to begin collaboration. Merely incremental improvements in the precision and accuracy of existing analytical techniques are not likely to produce significant advancements in nuclear forensic interpretation. However, significant advancements may do so. For example, some analytical techniques currently require more sample material than is typically available; research and development resulting in a significant decrease in the amount of material required would be important. In addition, techniques that reduce the limits of detection or improve spatial resolution may uncover totally new sources of signatures. Previous efforts at LLNL have moved signature discovery from the realm of bulk signatures (mm spatial scale) to micro-signatures (µm spatial scale). Continuing progress in reducing the spatial scale of nuclear forensic analyses into the realm of nano-signatures (nm spatial scale) may prove to be even more fruitful. On the other hand, techniques that measure entirely new properties of the material, properties independent from currently measured properties and strongly influenced by manufacturing process or location, could create significant breakthroughs for nuclear forensics.

Signature Discovery

More important to the nuclear forensics enterprise than improved analytical techniques, though, is the discovery of new signatures, properties of the material that reveal the source of the material, how it was made, why it was made, and where legitimate control of the material was lost. Signatures enable meaningful interpretation of the analytical results. However, for the same reason that signature discovery is more critical to nuclear forensics, it is also subject to increasing security and proprietary concerns.

We can address these concerns, in two ways. First, we can start by working together to identify signatures in lower-threat nuclear materials, such as uranium ores, uranium ore concentrates (yellowcake), UCl_4, UF_6, or reactor fuel pellets. The material characteristics of these materials will not be as sensitive as higher-threat materials, such as HEU or Pu. As we build trust in our cooperative enterprise, we may be able to work on materials of increasingly higher threat. Second, we can start developing generalized signatures, which cause less security concerns, and work towards more specific ones. For example, signatures in the isotopic composition of stable isotopes, e.g., oxygen in uranium oxide, are not specific to the isotopic composition of the fissionable material. We can develop our knowledge of signatures using lower-threat materials, such as natural uranium oxide, yet apply them to higher-threat materials, such as HEU oxide.

Knowledge Management & Analysis Techniques

The fully populated nuclear forensics database is expected to be vast, particularly considering the breadth of nuclear materials to be covered and the extensive list of materials properties that may be important. In addition to raw nuclear forensics data, we also need the ability to store information about production processes and locations throughout the history of nuclear materials production. Therefore, knowledge management is one area that is both important for the future of nuclear forensics and capable of being approached independently from concerns about data security.

Areas of productive collaboration might include methods for storing and managing all of this information, methods for analyzing these large amounts of multidimensional data in order to extract signatures using new, or at least newly applied, mathematical and statistical techniques. For example, at LLNL, we have developed iterative partial least squares discriminant analysis (PLSDA) for identifying the source of unknown uranium ore concentrate samples.[10]

Confidence Articulation

Ultimately, nuclear forensic scientists must deliver clearly stated conclusions to national decision makers based upon the analytical results and technical interpretation of those results, along with an appropriate estimate of the reliability of that answer. These conclusions will be reached by the application of multiple signatures, each with its own uncertainty, to multiple material analyses, each with its own uncertainty. All of these uncertainties must be incorporated into an overall level of confidence. This end goal will no doubt require the development of very sophisticated statistical methods, development that could be conducted independently of tightly held data and signatures.

Education & Training of Scientists for Nuclear Forensics

Nuclear forensics requires scientists and engineers with highly specific skills, for example, in nuclear engineering, radiochemistry, analytical chemistry, and geochemistry. Many of the existing experts in these fields are at, or near, retirement age. Because the demand for these skills decreased markedly after the cessation of nuclear weapons testing, new scientists and engineers with these skills have not been trained in great numbers.[11] Many university programs in these disciplines have disappeared or have decreased markedly. Now, these skills are once again needed for research, development, and execution of nuclear forensics analysis. Therefore, the training of young scientists and engineers is another area in which the Russian Federation and the United States might also collaborate.

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[10] M. Robel, M. Kristo, and M. Heller, "Nuclear Forensic Inferences Using Iterative Multidimensional Statistics," presented at 50th Annual Meeting of the Institute of Nuclear Materials Management, Tucson, AZ, July 12-16, 2009.

[11] M. May et al., "Nuclear Forensics: Role, State of the Art, Program Needs," report of the Joint Working Group of the American Physical Society and the American Association for the Advancement of Science, February 2008.

Future Nuclear Fuel Cycles

The worldwide growth in nuclear energy poses significant new challenges with regard to securing, safeguarding, monitoring and tracking nuclear materials. In order to reduce the risk of nuclear proliferation, new technologies must be developed to reduce the risk that nuclear material can be diverted from its intended use. Regardless of the specific nature of the fuel cycle, nuclear forensics and attribution will play key roles to ensure the effectiveness of non-proliferation controls and to deter the likelihood of illicit activities. Ensuring that individuals or organizations participating in illicit trafficking are rapidly identified and apprehended following theft or diversion of nuclear material will continue to provide the best deterrent against unlawful activities. Key to establishing this deterrent is developing the ability to rapidly and accurately determine the identity, source and prior use history of any interdicted nuclear material.

International Leadership

In the name of nuclear security cooperation and building capacity to combat terrorism, initiatives, such as the GICNT, call for enhancing ability to detect and suppress illicit trafficking and other illicit activities involving nuclear and radiological materials. Bilateral cooperation between the U.S. and R.F. in this area would improve technical capabilities, by bringing together our countries unparalleled expertise in the area of nuclear materials. Such cooperation would also set a significant precedent that might encourage greater international cooperation and sharing in this important non-proliferation and counterterrorism arena, particularly as the future international nuclear fuel cycle framework evolves.

CHALLENGES TO ADDRESS

In addition to the enormous opportunities presented by collaboration, there are also challenges that must be addressed.

Security

The primary obstacles to greater nuclear forensics collaboration between the United States and the Russian Federation are security concerns regarding sharing of data and knowledge. To further complicate this challenge, the security restrictions placed on information sharing in the two countries are not the same. For example, the United States considers the isotopic composition of its HEU to be unclassified, while the Russian Federation considers it a state secret. On the other hand, the United States considers the mass of certain components of its nuclear weapons to be classified, while the Russian Federation does not.

However, the U.S. and the Russian Federation have previously shared classified or sensitive information with each other, when the benefits of such sharing outweighed the risks. For example, as part of the HEU Transparency Program, some of the isotopic data that the Russians consider classified was shared with the U.S. Balancing the potential benefits, for both Russia and the U.S., of a greatly improved nuclear forensics system that enables rapid identification of nuclear material and improves counter-terrorism and non-proliferation capabilities, with national security concerns, should be explored more fully in the near future.

Funding

The U.S. has greatly increased the level of funding for nuclear forensics research and development since the terrorist attacks of September 11, 2001. Prior to this event, nuclear forensics was funded in a small way by far-sighted managers in the Department of Energy and by internal investments at a few of the national laboratories. However, despite this significant increase, the overall level of funding is still small compared to the vastness of the technical issues that need addressing. There continue to be multiple efforts, both inside and outside of the U.S. government, to assess the state of the U.S. nuclear forensics program, including the determination of the appropriate funding levels.

Nuclear forensics research & development performed in the Russian Federation has been largely funded by the U.S. at this point. In order to gain high-level support within the Russian government for increased funding of this area, we may need to emphasize the relevance of nuclear forensics to counter-terrorism and other areas of mutual concern.

Legal & Policy Framework for Cooperation

Much of our collaborative work in nuclear forensics has been conducted so far with reference to technical cooperation under the Nuclear Materials Protection, Control, and Accounting (MPC&A) Program. Although MPC&A is quite different from nuclear forensics, often the master task agreements negotiated under the MPC&A program are broad enough to accommodate nuclear forensic activities. Another umbrella agreement that was used in the past was the Warhead Safety and Security Exchange Agreements (WSSX), an agreement that provided for the exchange of unclassified technical information to enhance nuclear safety and security in both Russia and the United States. The International Science and Technology Center (ISTC), established in 1992, is a program that the U.S. has used to fund many cooperative research projects with Russian institutes. However, in August 2010, the Russian Federation announced its intention of leaving the ISTC.

There are several bilateral and international agreements that support the ultimate goal of nuclear forensics, i.e., the deterrence of nuclear smuggling and ultimately nuclear proliferation and terrorism. UN Security Council Resolution 1540 obligates states to take steps to prevent the spread of weapons of mass destruction and supporting technologies.[12] The Global Initiative to Combat Nuclear Terrorism, originally signed by Presidents George W. Bush and Vladmir V. Putin in 2006, has broad enough coverage to support many collaborative activities in nuclear forensics and related activities. In the context of these international agreements, new bilateral agreements between the U.S. and Russia may be required to support the data exchange necessary for a completely successful collaboration in nuclear forensics.

[12] To read the text of United Nations Security Council Resolution 1540, please see: http://daccess-dds-ny.un.org/doc/UNDOC/GEN/N04/328/43/PDF/N0432843.pdf?OpenElement; accessed May 26, 2010.

CURRENT EFFORTS

Current engagement between the U.S. and R.F. on nuclear forensics is occurring under the aegis of the Working Group on Nuclear Energy and Nuclear Security of the U.S.-Russia Presidential Commission, headed by U.S. Deputy Secretary of Energy Daniel Poneman and Rosatom Director-General Sergey Kiriyenko (the so-called "Poneman-Kiriyenko Working Group"). In March 2010, U.S. and Russian experts met in Moscow to discuss cooperative projects in nuclear forensics. On April 25-29, 2010, there was a meeting of the Joint Coordinating Committee for implementation of the Russian-U.S. intergovernmental Agreement regarding cooperation in the area of accounting, control and physical protection of nuclear materials, as well as forensics; based on the results of that meeting, a record was signed reflecting the results achieved and the areas for further cooperation, including a decision to incorporate nuclear forensics cooperation under the intergovernmental Agreement subject to Russian interagency concurrence. In June 2010, the U.S. submitted nuclear forensics cooperation proposals to Rosatom for consideration by the Russian interagency.[13]

CONCLUSION

Both President Obama and President Medvedev have recognized the special responsibility of the United States and Russia for nuclear security and, through the 2010 Nuclear Security Summit Communiqué and Work Plan, have joined other countries in acknowledging the importance of bilateral and multilateral cooperation to develop national capacities in nuclear forensics. Current efforts under the Poneman-Kiriyenko Working Group build upon several successful collaborations between the U.S. and R.F. in nuclear forensics with the goal of achieving an active partnership in advancing nuclear forensics in support of international nuclear security.

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[13] Joint Report, 2009-2010 Results of the U.S.-Russia Presidential Commission, http://www.state.gov/p/eur/ci/rs/usrussiabilat/144091.htm; accessed May 26, 2010.