CHAPTER 3

NOVEL TECHNOLOGIES FOR THE DETECTION OF UNDECLARED NUCLEAR ACTIVITIES*

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INTRODUCTION

The International Atomic Energy Agency (IAEA) works to maximize the contribution of nuclear technology to human endeavors, while verifying its peaceful use. The IAEA's mission is addressed by science and technology, mobilizing peaceful applications of nuclear science and technology to developing countries; by safety and security, protecting people and the environment from harmful radiation exposure; and by safeguards and verification, preventing the further spread of nuclear weapons. In the area of safeguards and verification, the IAEA carries out inspection activities that include confirming a state's declared nuclear material (including plutonium and enriched uranium) and maintaining vigilance for evidence of undeclared nuclear material and activities. In exceptional circumstances, the IAEA may also be granted special responsibilities under United Nations Security Council (UNSC) resolutions, allowing it to search for and uncover covert nuclear weapons programs (e.g., following the 1991 Gulf War), or to conduct ongoing monitoring of disarmament (e.g., monitoring the freeze on reprocessing plutonium under the 1994 framework agreement with the Democratic People's Republic of Korea (DPRK).

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In 2004, the IAEA General Conference called upon the Secretariat to examine innovative technological solutions to strengthen the effectiveness and improve the efficiency of IAEA safeguards. Member States also agreed to provide appropriate assistance to facilitate the exchange of equipment, material, and scientific and technological information for the implementation of additional protocols. The project Novel Techniques and Instruments for Detection of Undeclared Nuclear Facilities, Material, and Activities (known as the Novel Technologies Project) was established in 2005 to identify specific needs and initiate the necessary research and development (R&D) of techniques and instruments that will be used for the implementation of additional protocols, including the conduct of complementary access.

The IAEA Strategic Objectives for 2006-11[1] include the enhancement of the IAEA's detection capabilities through the development of new or improved safeguards approaches and techniques, and the acquisition of more effective verification equipment. The following goals are applicable to the Novel Technologies Project:

- Improve current detection capability;
- Pursue R&D for the development of novel technologies for detection of undeclared activities;
- Utilize, *inter alia*, Member States Support Programme (MSSP) mechanisms as well as internal resources and expertise; and,
- Optimise safeguards equipment and technology.

DEVELOPMENT AND IMPLEMENTATION OF SAFEGUARDS METHODS AND INSTRUMENTS

Implementation of effective and efficient safeguards has increasingly relied on the development and deployment of methods and instruments meeting specific functional and technical requirements. Accordingly, equipment development has complemented the safeguards implementation approaches. For example, early safeguards equipment was developed in support of on-site verification of materials and activities at declared locations.

After the 1991 Gulf War and the discovery of a clandestine nuclear weapons program in Iraq, safeguards approaches were enhanced to include additional methods and techniques, providing the IAEA with further tools by which it could better detect undeclared activities. These included environmental sampling, information analysis, export monitoring, satellite imagery, and new technologies such as ground penetrating radar. New technologies were also developed in support of additional protocols activities, including those for complementary access.

By their very nature, clandestine weapons programs take place at undeclared locations or at declared locations that may be used as a "cover" for an undeclared process being carried out. The location of such activities requires appropriate equipment that can detect unique characteristics related to the particular activity. The Novel Technologies Project aims to broaden the range of techniques and instruments available to the IAEA, including emerging techniques and instruments that enable the IAEA to detect undeclared activities in undeclared locations (e.g., small industrial areas, universities, and workshops).

THE NOVEL TECHNOLOGIES PROJECT

In 2005, the IAEA Department of Safeguards solicited suggestions and proposals through its MSSP system. Broad requirements based on safeguards needs were prepared and sent to all MSSPs and other international bodies. Over 60 proposals, covering a wide range of techniques, were received and reviewed by the Safeguards Department. Techniques regarded as "new"[2] were forwarded to the relevant organizational unit in the IAEA for further consideration. Those regarded as "novel"[3] methods or instruments addressing a particular safeguards problem were selected for further development and evaluation within the Novel Technologies Project. Interestingly, many were based on emerging laser and other forensic techniques.

Project Tasks.

The following proposals, meeting specific safeguards needs for both on-site and away-from-site detection of undeclared activities, have been selected by the IAEA for further development and evaluation.

Optically stimulated luminescence (OSL).

Need: To determine if an undeclared location has been used previously for storing radiological material.

Figure 1. An undeclared location is used for storage of undeclared materials.

Figure 2. The materials are removed and the location is subsequently "disquised."

Proposed Solution: Use OSL to measure the radiation-induced signature retained in many common building materials.

Figure 3. An IAEA inspector collects samples of the surrounding building materials.

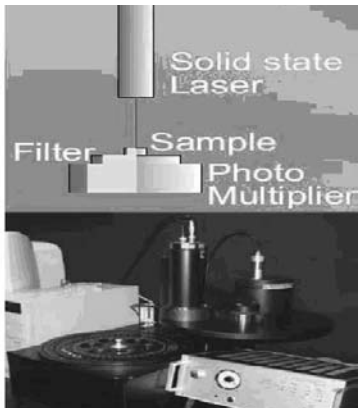

Figure 4. The collected samples are analyzed for residual nuclear activation, indicating the previous presence of stored nuclear materials.

Need: To determine the nature and history of compounds and elements found on site.

Figure. 5. Unidentified materials found during an on-site complementary access inspection.

Proposed Solution: Use on-site LIBS to determine the nature and history of compounds and elements.

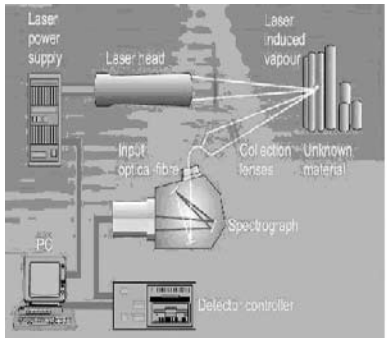

Figure 6. LIBS comprises (i) a laser system to ablate the material surface to create a micro-plasma, and (ii) a spectrometer to generate a spectroscopic profile of the micro-plasma's constituent components.

Figure 7. A trained IAEA inspector operates the LIBS unit on-site. The spectroscopic profile is compared to those in its library to determine material's make-up and history.

Light detection and ranging (LIDAR).

Need: To detect the presence and nature of nuclear fuel cycle process activities at suspected locations.

Proposed Solution: Use a mobile LIDAR laboratory in the vicinity of a suspected site to detect the presence of characteristic gaseous compounds, emanating from nuclear fuel cycle (NFC) processes into the atmosphere.

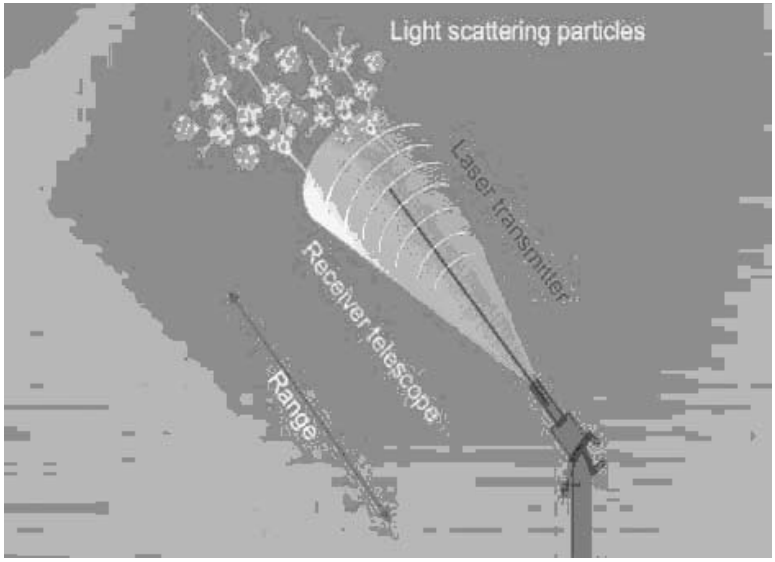

Figure 8. LIDAR methods are used routinely by environmental monitoring agencies to determine the presence of pollutants in the atmosphere.

Figure 9. A mobile LIDAR travels to the vicinity of a suspected location engaged in undeclared NFC processes. A laser, tunable to precise wavelengths (λ) selectively stimulates specific airborne molecules emanating as gaseous compound from the process. A light-sensitive telescope scans the atmosphere, detecting the presence of the stimulated molecules.

Sampling and analysis of atmospheric gases.

Need: To detect the presence and nature of nuclear fuel cycle process activities at suspected locations.

Proposed Solution: Use on-site laboratory to determine the atmospheric composition of gaseous mixtures.

Figure 10. A mobile on-site laboratory samples and concentrates atmospheric-borne pollutants. Local meteorological conditions and the GPS location are also recorded.

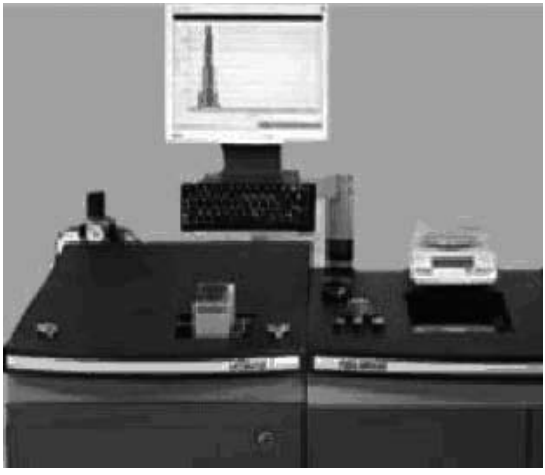

Figure 11. Samples are brought to a field laboratory for analysis.

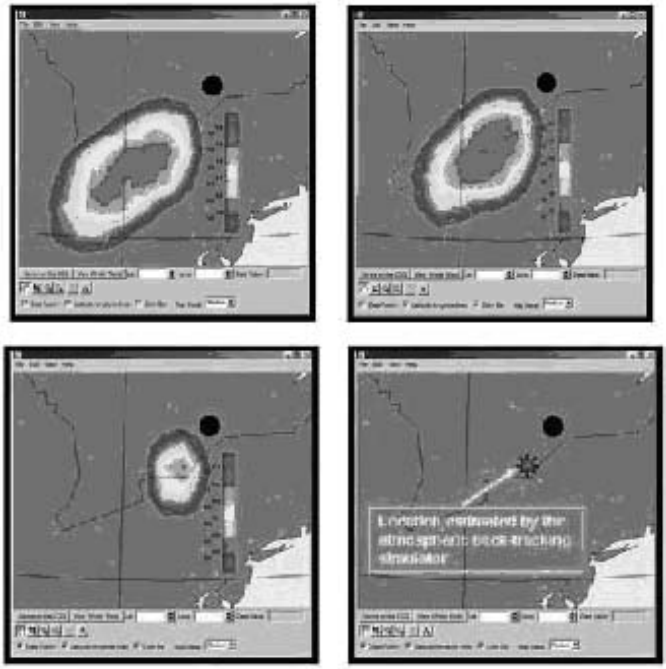

Figure 12. Airborne material is identified through sample analysis, and the data are combined with meteorological information in a suitable atmospheric computer model to provide an estimate of the source direction and probable location.

Project Activities.

In parallel to pursuing the tasks outlined in Project Tasks, the Project has also convened specialist technical meetings on techniques for the verification of enrichment activities,[4] noble gas sampling and analysis,[5] and laser spectrometry techniques.[6] Further specialist meetings covering novel technologies are being planned. Additionally, the Project has been active with the support of Member States in establishing

contacts with international R&D organizations and with experts engaged in a wide range of sensor and detection technologies. MSSPs have also been supportive, agreeing to assist the Project by facilitating technical exchanges with both private and government-operated R&D laboratories and by providing access to experts for short-duration tasks, facilitating attendance at technical meetings, advising on novel methods and instruments, conducting field tests and providing supplementary funding.

The Project is also developing a secure technical database to handle relatively large volumes of technical information. The database will also provide nonsensitive information on the Project's tasks and activities on a dedicated website to further raise the profile of this work to the international R&D community.

Project Planning.

The Novel Technologies Project was established to develop and evaluate effective techniques that meet IAEA needs and that can be incorporated within safeguards approaches for detecting evidence of undeclared nuclear fuel-cycle activities, particularly at undeclared locations. To that end, the Project will continue to conduct surveys to identify safeguards needs that cannot be met with available techniques, broaden technical collaboration with other nonproliferation organizations and the international R&D community and, where required, initiate further tasks that will lead to safeguards-useable methods and instruments. The basis of these initiatives will be a review and analysis of the nuclear fuel cycle processes, the identification of the most safeguards-useful activity indicators[7] and emanating signatures[8] that can "travel" from the

source location and be detected with a high level of confidence and accuracy. Indicators and signatures will be information, matter, and/or energy associated with a particular NFC process. Once identified, methods useful for the detection of promising indicators, and signatures will be assessed by experts to determine if suitable methodology or instruments are available. Where none exist in a safeguards-useable form, then the Project will define appropriate technical and procedural requirements, initiating the necessary R&D and testing regimes.

CONCLUSIONS

The establishment of the Novel Technologies Project has provided a mechanism for the IAEA to address the technologies required for emerging and future inspectorate needs. Moreover, it has facilitated the IAEA's access to a greatly expanded range of methods and instruments, thereby allowing safeguards planners the opportunity to develop novel verification and detection approaches.

REFERENCES

International Atomic Energy Agency, *Technical Meeting on Techniques for IAEA Verification of Enrichment Activities, STR-349*, Vienna: International Atomic Energy Agency, 2005.

International Atomic Energy Agency, *Strategic Objectives 2006–2011*, Vienna: International Atomic Energy Agency, 2006.

International Atomic Energy Agency, *Technical Meeting on Application of Laser Spectrometry Techniques in IAEA Safeguards*, Vienna: International Atomic Energy Agency, 2006.

International Atomic Energy Agency, *Technical Meeting on Noble Gas Monitoring Sampling and Analysis for Safeguards*, Vienna: International Atomic Energy Agency, 2006.

ENDNOTES - CHAPTER 3

1. International Atomic Energy Agency, *Strategic Objectives 2006-2011*, Vienna: International Atomic Energy Agency, 2006.

2. New technologies are defined as those for which the methodology is already understood and implemented by the IAEA for safeguards applications. Examples include the next generation surveillance and sealing system.

3. Novel technologies are defined as those for which the methodology has not been applied previously by the IAEA for safeguards applications.

4. International Atomic Energy Agency, *Technical Meeting on Techniques for IAEA Verification of Enrichment Activities, STR-349*, Vienna: International Atomic Energy Agency, 2005.

5. International Atomic Energy Agency, *Technical Meeting on Noble Gas Monitoring Sampling and Analysis for Safeguards*, Vienna: International Atomic Energy Agency, 2006.

6. International Atomic Energy Agency, *Technical Meeting on Application of Laser Spectrometry Techniques in IAEA Safeguards*, Vienna: International Atomic Energy Agency, 2006.

7. Indicators are defined as entities that go into making the process operative. Examples are resources, required materials, facility design and related R&D.

8. Signatures are defined as entities produced by the nuclear fuel cycle process when it is in operation Examples are produced material, process by products and energy emanations.