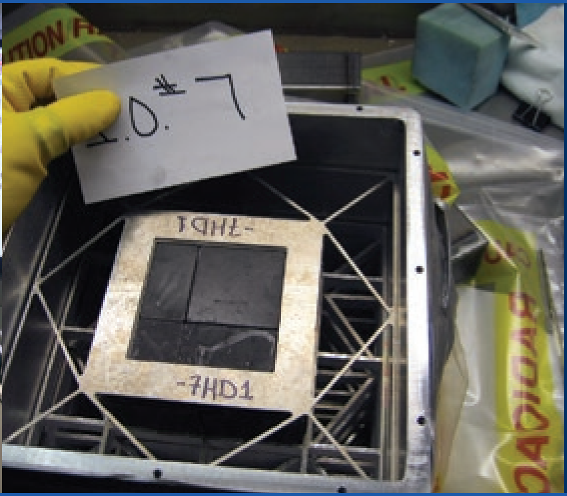


Joint U.S.-U.K. Report on Technical Cooperation for Arms Control

To develop and evaluate methodologies and technologies to verify potential nuclear weapon treaties, in support of shared U.S.-U.K. commitment to Article VI of the Nuclear Non-Proliferation Treaty.

National Nuclear Security Administration

OFFICE OF
NONPROLIFERATION AND
ARMS CONTROL (NPAC)

Ministry
of Defence

AWE

Table of Contents

A U.S. monitor conducts an inspection using an optical polarimetry technique during the 2011 WMD Exercise.

Overview

This *Joint U.S.-U.K. Report on Technical Cooperation for Arms Control* documents the first 15 years of collaboration—from 2000 to 2015—between the United Kingdom and the United States in technologies and methodologies to enable monitoring and verification of potential future nuclear weapons arms control initiatives. This collaboration, motivated by a shared U.S.-U.K. commitment to Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), has proven to be an essential tool for exploring, developing, evaluating and exercising possible approaches for warhead verification, with a particular emphasis on developing and evaluating potential capabilities to confirm dismantlement of nuclear warheads.

The United Kingdom and the United States recognized from the outset that to enable nuclear warhead verification in the future, and in particular to enable verification of sensitive processes at nuclear weapons facilities, a number of technical, legal, operational and security challenges must be understood and addressed. Since its inception, the U.S.-U.K. technical collaboration program has provided a unique and valuable platform for testing and evaluating the viability of concepts for monitoring future arms control and nonproliferation initiatives, while balancing the range of challenges involved. From initial exchanges to familiarize each other with research accomplishments and directions, to the integration of accumulated joint research and analysis into increasingly realistic warhead dismantlement exercises, the program has sought to apply policy, technology and operations expertise to develop and evaluate targeted approaches for transparent reductions and monitoring of nuclear warheads, components, fissile materials and associated facilities.

The unique relationship between the United Kingdom and the United States, and specifically the two countries' ability to exchange classified nuclear weapons information in accordance with the terms of the 1958 Mutual Defense Agreement (MDA), provides the framework for investigating highly sensitive issues in depth. The ability to exchange classified information has provided a secure environment where verification methodologies designed to protect classified or sensitive information can be tested, with the reassurance that if developmental techniques fail, the information has been authorized for exchange and will remain protected within the framework of the 1958 MDA. This has allowed the United States and the United Kingdom to test and evaluate methodologies on actual warheads and components, thereby providing very high levels of confidence with regard to the viability of different monitoring and measurement techniques.

Through joint collaboration, the United Kingdom and the United States have worked to develop consensus on technologies and technical procedures that could be used for potential future arms control or nonproliferation initiatives. This collaboration has included evaluating technologies and approaches that may be viable, identifying those that are not, and documenting challenges and approaches that need additional investigation. Working bilaterally has helped develop a broader base of technical expertise and has enhanced the working relationships between the two countries' technical experts. The 15 years of experience working together on monitoring and verification technical challenges has helped establish an experience base in both countries that has permitted deeper investigation into some of the most challenging aspects of warhead verification.

The United Kingdom and the United States look forward to building on the extensive body of research completed during the first 15 years of joint U.S.-U.K. technical collaboration on nuclear disarmament verification. Work to date provides an essential basis for advanced equipment development and integration of technologies and methodologies into more complete and robust regimes for future exercise and evaluation. The United Kingdom and the United States are committed to advancing this body of international research in support of future international initiatives and meeting shared obligations under Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons.

The purpose of this report is to provide insight into this unique collaboration and to stimulate further consideration of technical issues associated with nuclear weapons arms control verification.

Lessons Learned

U.S.-U.K. technical collaboration has yielded a number of lessons learned. Many pertain to specific measurements and monitoring techniques, while others have applicability across different monitoring approaches. An overarching lesson learned is that the ability to strike a balance between information protection and information sufficiency is key to an effective monitoring and verification regime. A monitoring party must be able to obtain sufficient data to confirm declarations, while a host party must have assurances that their most sensitive information is protected throughout the monitoring and verification process. This balance has guided the U.S.-U.K. cooperative program since its beginning and has resulted in several conclusions that will continue to guide the U.S.-U.K. technical cooperation program in the future. Key lessons learned from joint U.S.-U.K. technical collaboration are:

- The opportunity to test and evaluate technologies and processes in operational environments is essential for understanding actual capabilities and feasibility.
- There are many difficult and highly complex classification, access, technology and legal challenges that will need to be addressed to implement a warhead dismantlement verification regime. From a technical perspective, however, monitoring and verification of nuclear warheads, components and sensitive processes is feasible.
- Developing the necessary technologies and approaches to successfully monitor warhead dismantlement takes time. Warheads and associated processes are complex. Safety and security procedures are exceptionally rigorous and not amenable to change.
- Familiarity with concepts and practice with approaches pays important dividends. Ongoing bilateral technical cooperation helps both countries gain confidence in their ability to protect classified and sensitive information and determine where work is still needed.

Looking ahead, the United Kingdom and the United States anticipate further sharing of technical results and more formal prioritization of future research objectives based on experiences and lessons learned to date.

U.S. and U.K. representatives discuss methods for verification of nuclear disarmament on the margins of the 2014 Preparatory Commission meeting for the 2015 NPT Review Conference.

Applicability to International Community

The U.S.-U.K. cooperative program has focused on identifying and developing technologies and procedures that protect classified and sensitive unclassified information while allowing:

- Managed access for inspectors at nuclear weapons facilities;
- Confirmation of declared nuclear weapon attributes;
- Chain of custody for nuclear warheads and components through the dismantlement process;
- Monitored storage of nuclear weapons, components and materials; and
- Authentication of inspection equipment.

While every State has different guidelines with regard to what it considers classified, an essential point for the broader international community is the obligation that exists under the NPT not to disclose information that could enable the proliferation of nuclear weapons. The results of the technical collaboration between the United Kingdom and the United States suggest that future engagement between Nuclear Weapon and Non-Nuclear Weapon States for the purpose of nuclear weapons arms control verification—while exceptionally challenging—is nevertheless feasible.

The United Kingdom and the United States began briefing joint activities in the context of engagement among the five recognized nuclear weapon states under the NPT (the P5) in 2009 and in 2014 provided the first joint presentation to the broader international community on the margins of the Preparatory Committee for the 2015 NPT Review Conference at the United Nations in New York. The U.S. and U.K. Governments will consider providing information at appropriate points in the future to help spur international collaboration—among Non-Nuclear Weapon States, among the Nuclear Weapon States and between Nuclear and Non-Nuclear Weapon States—to build on the results and lessons learned through joint cooperation.

ARTICLE VI

Article VI of the Treaty on the Nonproliferation of Nuclear Weapons

"Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control."

The obligations of Article VI of the NPT are shared by the international community. Among the many technical and international security conditions that must be considered along the path toward a world without nuclear weapons, effective means of verification is a necessity. The Nuclear Weapons States are in a unique position to contribute approaches for effective verification.

A Look Ahead

The results of ongoing collaborative activities will further inform next steps. These current activities include the joint development of a radiation portal monitor for arms control monitoring applications and the completion of a multi-year warhead measurement and modeling campaign to inform future warhead verification research. In addition, the United Kingdom and the United States will continue investigations to identify and resolve capability gaps in key enabling areas, including chain of custody and data authentication, while working to draw from other applicable fields of research.

Program Beginnings

MUTUAL DEFENSE AGREEMENT

The 1958 Agreement between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the United States of America for the Cooperation on the Uses of Atomic Energy for Mutual Defense Purposes (MDA) authorizes the exchange of nuclear-related classified information between the United States and the United Kingdom. It advances the common defense and security of both nations.

Cooperation between the United Kingdom and the United States in arms control and nonproliferation technology followed from the results of the 1998 U.K. Strategic Defence Review, which asserted that U.K. nuclear weapons would be included in future multilateral negotiations and that the United Kingdom would require confidence that other parties to such arms control treaties were in compliance with their obligations. Consequently, the U.K. Ministry of Defence directed the U.K. Atomic Weapons Establishment (AWE) to establish a Verification Research Program to position AWE to advise the British Government on nuclear arms control. AWE sought to investigate the U.K. capability to provide verification support for future multilateral nuclear arms control initiatives. The April 2000 AWE "Confidence, Security & Verification Report" focused on research needed to develop verification technologies. After completion of the study, the U.K. Ministry of Defence and AWE sought to engage with the United States.

U.S.-U.K. cooperation under the 1958 MDA officially began in October 2000 with a joint meeting at AWE during which U.S. and U.K. Government and laboratory participants exchanged information on relevant work and explored the feasibility and objectives of joint collaboration. U.S. information provided during this initial meeting included presentations on the Department of Energy's Warhead and Fissile Material Transparency (WFMT) Program, the U.S.-Russia lab-to-lab program and the joint U.S. Department of Defense-Department of Energy Integrated Technology Implementation Plan for coordinated U.S. Government development of monitoring and verification technology. These programs each had beginnings in anticipated future agreements with Russia that would potentially require fissile material and nuclear warhead monitoring. During the course of the first joint meeting, the United States and United Kingdom developed a cooperative path forward to address mutually beneficial collaboration.

Major U.S.-U.K. Arms Control Cooperation Activities

2001	Joint Measurement and Data Analysis	Joint Measurement Campaign, April 2001
2002	Managed Access Exercise	Familiarization Visit to Burghfield, May 2002
2003	Joint Measurement and Data Analysis	Joint Diagnostics Exercise, March 2003
2005	Joint Measurement and Data Analysis	Rocky Ridge, June 2005
2006	Managed Access Exercise	Familiarization Exercise at Pantex, February 2006
	Focused Experts' Workshops and Meetings	TID/TIE Workshop, April 2006
2007	Focused Experts' Workshops and Meetings	Information Barrier Workshop, April 2007

U.S. and U.K. scientists pause for a photo with an inspection object used at the first Joint Measurement Campaign, hosted by the U.K. in April 2001.

From both the U.S. and U.K. perspectives, the ability to engage with each other offered an important opportunity to test and evaluate nuclear warhead monitoring and verification capabilities within operational environments where the exchange of classified information could be permitted if necessary. This was—and remains—an essential aspect of U.S.-U.K. cooperation, as concepts and technologies intended to protect classified information during verification activities can be tested in operational facilities without risking a security incident should an approach fail. It further provided both the United Kingdom and the United States additional perspective with regard to another country's operational environment, safety and security requirements, constraints, unique challenges and monitoring objectives.

In February 2001, representatives from the United Kingdom visited the Los Alamos National Laboratory and Sandia National Laboratories and participated in tours of the Pantex Plant in the United States to increase understanding of U.S. weapons handling and process activities. The first joint measurement campaign was conducted at AWE in April 2001, during which U.S. and U.K. technologies were used to conduct measurements on warheads and components, including measurement techniques that could be applied throughout a warhead's disassembly. Following these initial exchanges and cooperative measurement activities, the U.S. and U.K. Governments agreed to establish under the auspices of the MDA, a dedicated channel for cooperation for work in the area of nonproliferation and arms control technology. This channel was formalized at the end of 2001. Since that time, the United Kingdom and the United States have participated in multiple managed access exercises, joint measurement and data analysis events, workshops and technical exchanges, each of which has informed successive activities and has led to increasingly challenging and technically complex collaborative initiatives.

Managed Access Exercise
PG Exercise, September 2008

2008

Focused Experts' Workshops and Meetings
Authentication Workshop, March 2009

2009

Managed Access Exercise
Warhead Monitored Dismantlement (WMD) Exercise, July 2010 – December 2011

Joint Measurement and Data Analysis
Active Measurement Campaign, September 2010

Focused Experts' Workshops and Meetings
Monitored Storage Visit, February 2010

2010

2011

Joint Measurement and Data Analysis
MG 1, April 2013

2013

Joint Measurement and Data Analysis
MG 3, July 2014

Focused Experts' Workshops and Meetings
Authentication Workshop, June 2014

2014

🟩 Managed Access Exercise
🟧 Joint Measurement and Data Analysis
🟪 Focused Experts Workshops and Meetings

Managed Access Exercises

KEY OBJECTIVES OF MANAGED ACCESS

- Permit agreed level of access
- Protect operational security information
- Prevent physical or visual access to production activities and equipment
- Prevent the collection and release of sensitive information not subject to monitoring provisions
- Prevent the collection and removal of physical samples of materials
- Prevent the introduction of unauthorized equipment and materials
- Prevent the tampering with or disabling of equipment

From 2002 through 2011, the United Kingdom and United States conducted four major managed access exercises, concluding with an extensive Warhead Monitored Dismantlement exercise that benefited from the range of cooperative activities conducted during the first decade of collaboration, including the joint measurement and data analysis events and subject-specific technical exchanges and workshops. These managed access exercises provided the opportunity to explore the feasibility and challenges associated with permitting access

Familiarization Visit to AWE Burghfield

An important aspect of the early work on verification explored the managed access concept in the context of nuclear weapon dismantlement verification. The United Kingdom considered a visit to AWE of a P5 delegation a conceivable confidence building precursor to any future nuclear arms control agreement involving the United Kingdom. Consequently, the United Kingdom proposed the preparation and completion of a “familiarization visit” exercise at the U.K. Burghfield weapons facility as the first formal activity under the MDA. This was completed in May 2002.

The managed access concept exercise was based on experiences gained from routine regulatory inspections, as well as simulated challenge inspections under the Chemical Weapons Convention (CWC). It was conducted in the assembly/disassembly area of AWE, a highly secure area in which warheads and warhead components are handled and assembled into or disassembled from complete nuclear warheads. Visual access to this area could potentially reveal sensitive nuclear warhead design information. Access to the area, even for security-cleared personnel, is strictly controlled.

This was a challenging exercise for all concerned. The key players reported that it took people well outside their comfort zones. The negotiation phase put considerable pressure on the Host Team Leader, and initially a number of minor issues escalated into disagreement and mistrust. As time went on, however, the teams started to talk constructively and reach compromises.

The exercise proved very successful, providing a wealth of information that has helped to clarify the considerable challenges in admitting foreign visitors into such facilities for verification of nuclear warhead reductions. The opportunity to test ideas and methodologies in a real environment was extremely valuable and the participants learned useful lessons about the challenges of carrying out this activity and options for managing them.

of monitoring teams to sensitive nuclear facilities, and testing and demonstrating a range of measurement techniques and chain-of-custody procedures.

Collectively, the exercises demonstrated that implementing a warhead dismantlement verification regime will require the resolution of many classification, access, technology and legal challenges, which require foresight, preparation, ingenuity and resources to overcome. These challenges can be compounded by: limitations imposed by facility, security and safety requirements, including limits on the number of monitors, escorts and technicians allowed in a facility; availability of host personnel; operating hours of the facility; availability of essential equipment; and preparation time. Despite these challenges, there are possibilities for creative approaches to support monitoring and verification, even in some of the most sensitive and challenging operational environments.

Brief descriptions of the managed access exercises are below. The table on page 10 provides comparison information about the scenario, purpose, objectives and results of each exercise.

Familiarization Exercise at Pantex

To build on and further develop the managed access lessons learned during the Familiarization Visit to Burghfield in 2002, the U.S. Pantex Plant hosted a follow-on Familiarization Exercise in 2006. The exercise focused on familiarization with all areas of the Pantex facility to which access was needed for comprehensive monitoring of the dismantlement process. These included areas associated with: receipt of a warhead from the field; on-site interim storage pending dismantlement; disassembly; removal of nuclear and non-nuclear components and sub-assemblies; post-dismantlement interim storage of components; destruction of non-nuclear components; and on-site storage or loading for shipment to another facility of nuclear components, sub-assemblies and material. The goal was to develop an understanding of the dismantlement process at this facility sufficient for future joint development of a detailed plan for a monitored dismantlement regime at Pantex. While development of such a plan was itself beyond the scope of the exercise, the exercise showed that with careful application of managed access principles, it was possible in principle to grant controlled access to the necessary facilities and processes while protecting sensitive information.

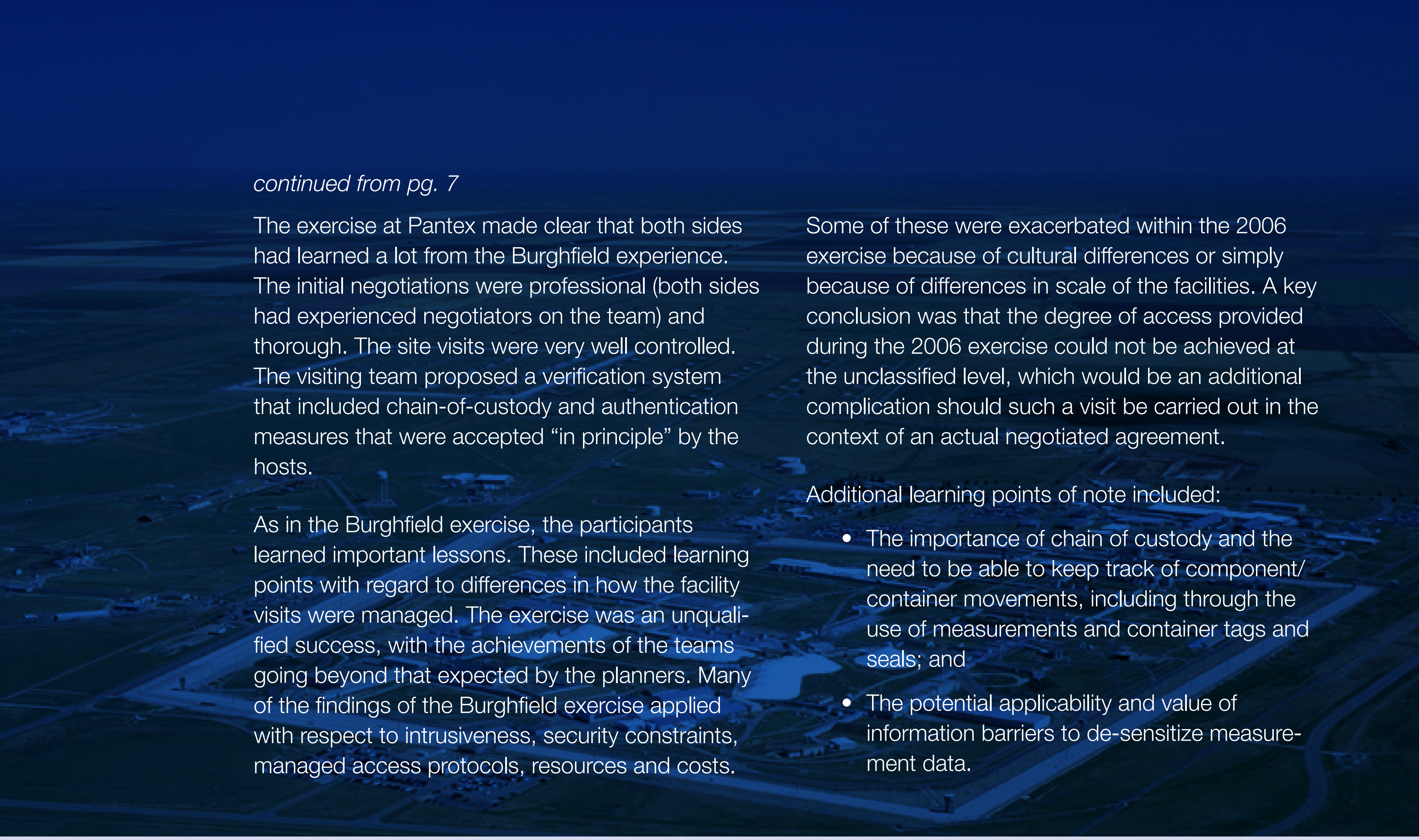
continued on pg. 8

EXERCISES HIGHLIGHT DIFFERENCES IN PHILOSOPHIES

By exercising managed access at both U.S. and U.K. sites, the United Kingdom and the United States realized that facilities in the two countries can take very different approaches to enabling certain accesses while protecting information. For the 2002 Burghfield visit, the facility made the decision to allow limited discussion between visitors and appropriately briefed facility staff who worked in key areas to build confidence that the facilities and activities were as declared. While this increased the risk of inadvertently transmitting sensitive information, the philosophy was that with appropriate preparation, selected facility staff could answer questions and explain facility activities in an unclassified way and so promote confidence in the visiting party. This approach worked well; despite some searching questioning by the inspecting team, no sensitive information was divulged.

In contrast, for the 2006 Pantex visit, the facility prepared in advance scripted answers to anticipated questions to ensure the material could be reviewed and that sensitive information was not divulged unintentionally. This approach initially left visitors wondering if the personnel they were engaging were actual facility staff or not. However, as the exercise progressed, and as more information was provided in response to questions, confidence improved.

Pantex Plant



continued from pg. 7

The exercise at Pantex made clear that both sides had learned a lot from the Burghfield experience. The initial negotiations were professional (both sides had experienced negotiators on the team) and thorough. The site visits were very well controlled. The visiting team proposed a verification system that included chain-of-custody and authentication measures that were accepted “in principle” by the hosts.

As in the Burghfield exercise, the participants learned important lessons. These included learning points with regard to differences in how the facility visits were managed. The exercise was an unqualified success, with the achievements of the teams going beyond that expected by the planners. Many of the findings of the Burghfield exercise applied with respect to intrusiveness, security constraints, managed access protocols, resources and costs. Some of these were exacerbated within the 2006 exercise because of cultural differences or simply because of differences in scale of the facilities. A key conclusion was that the degree of access provided during the 2006 exercise could not be achieved at the unclassified level, which would be an additional complication should such a visit be carried out in the context of an actual negotiated agreement.

Additional learning points of note included:

- The importance of chain of custody and the need to be able to keep track of component/container movements, including through the use of measurements and container tags and seals; and
- The potential applicability and value of information barriers to de-sensitize measurement data.

PG Exercise

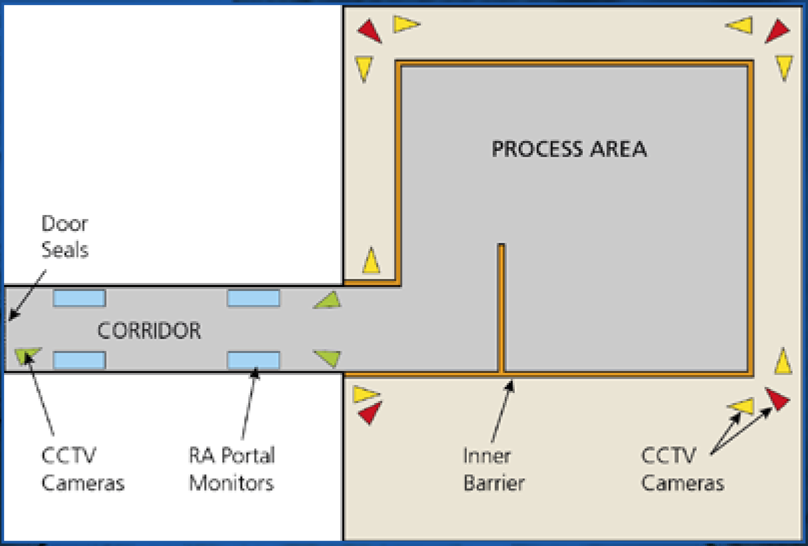
Building on the lessons learned from the 2002 Familiarization Visit to AWE and the 2006 Familiarization Exercise at the Pantex Plant, an exercise, designated “PG,” was conducted at the AWE Burghfield Plant in 2008 with the objective of establishing the chain of custody for the dismantlement of two warheads according to the terms of a hypothetical agreement.

The PG Exercise attempted to strike an optimal balance between realism and necessary artificialities. Several elements of a full chain-of-custody monitoring regime remained notional for this exercise, including the use of continuous video surveillance and the implementation of an information barrier; for the PG exercise a physicist from Lawrence Livermore National Laboratory performed information barrier functions manually. In addition, out-of-role discussions between the U.S. and U.K. teams were necessary to make assumptions or introduce artificialities that enabled the exercise to move forward. Differences between the Pantex and Burghfield security evaluation of proposed technical measures (e.g., video surveillance of operations, electrical power options, measurement techniques) became evident in comparing the 2006 and 2008 exercises. This resulted in the consideration of additional monitoring options and the opportunity to more clearly articulate the options proposed and the potential safety and security hazards that may accompany them.

All aspects of a complete monitored dismantlement regime were represented in the exercise, although several of the required confirmation measurement procedures were played only notionally.

Warhead Monitored Dismantlement Exercise

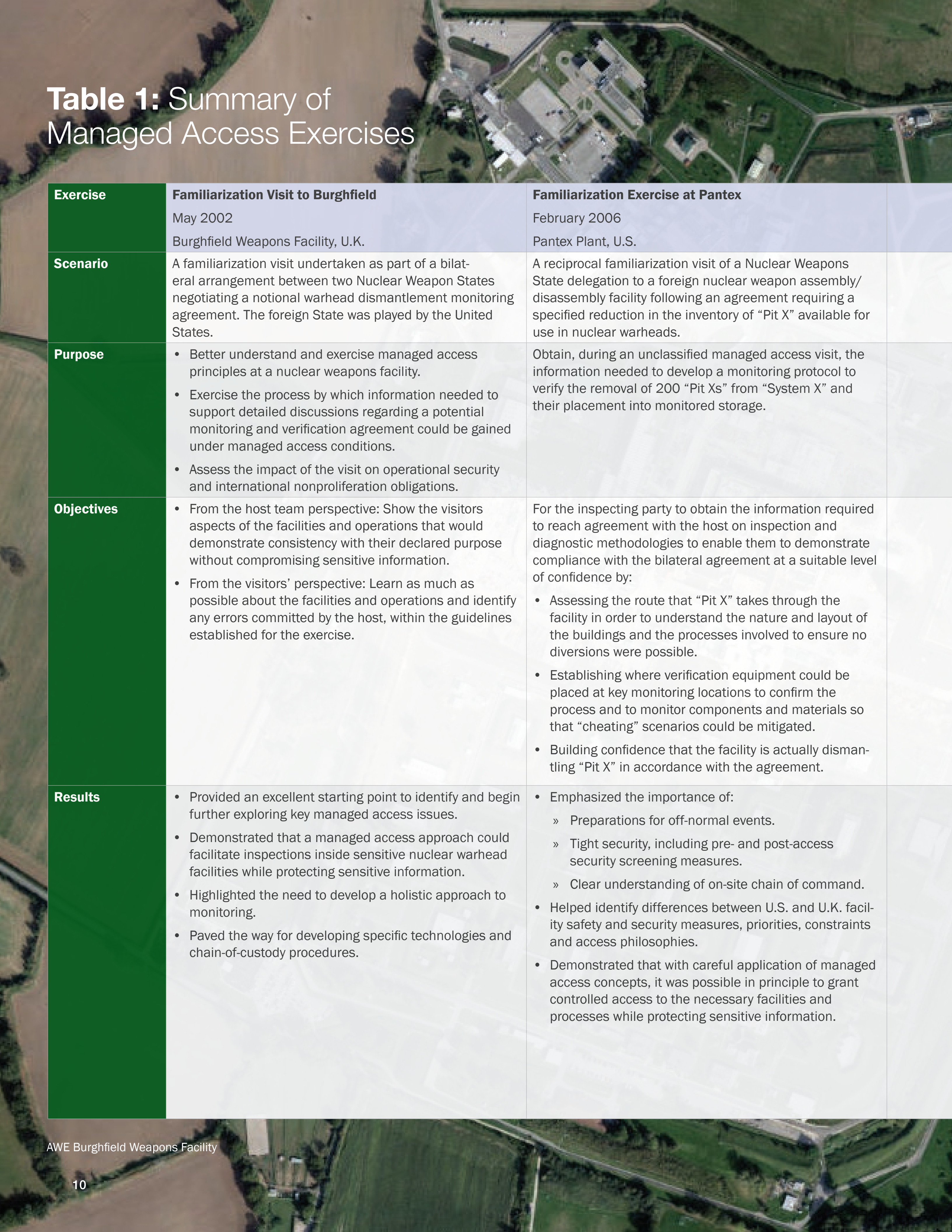
The Warhead Monitored Dismantlement (WMD) Exercise, completed in 2011, built on and added to the body of research and analysis that had been acquired through more than a decade of U.S.-U.K. cooperation. In the 18 months leading up to the exercise, the United States and the United Kingdom played fictitious countries negotiating an agreement and protocol containing basic provisions for mutual nuclear weapon reductions to be accomplished through monitored dismantlement. The monitored dismantlement of a high-fidelity mock-up nuclear device with actual fissile material and simulated high explosives was performed in an operational nuclear facility in the United Kingdom. Planning activities included: monitoring regime scope discussions and negotiations; a familiarization visit; Joint Chain of Custody Working Group and Joint Nondestructive Assay Methods Working Group meetings to evaluate specific monitoring techniques and procedures; and the actual monitoring visit and exercise in November 2011.



Top: Room-within-a-Room was a system of procedures and technologies developed and deployed during the WMD Exercise to account for items throughout the dismantlement process and provide confidence that special nuclear material was not diverted or substituted during the process. The Room-within-a-Room created a controlled boundary around disassembly operations using multiple complementary technologies (cameras, tamper indicating panels and enclosures, seals, unique identifiers and radiation portals). **Bottom:** A U.S. monitor conducts an inspection using an optical polarimetry technique during the 2011 WMD Exercise. **Background:** A U.K. host takes a reference image of a seal during the WMD Exercise while a U.S. inspector observes.

Table 1: Summary of Managed Access Exercises

Exercise	**Familiarization Visit to Burghfield** May 2002 Burghfield Weapons Facility, U.K.	**Familiarization Exercise at Pantex** February 2006 Pantex Plant, U.S.
Scenario	A familiarization visit undertaken as part of a bilateral arrangement between two Nuclear Weapon States negotiating a notional warhead dismantlement monitoring agreement. The foreign State was played by the United States.	A reciprocal familiarization visit of a Nuclear Weapons State delegation to a foreign nuclear weapon assembly/disassembly facility following an agreement requiring a specified reduction in the inventory of "Pit X" available for use in nuclear warheads.
Purpose	• Better understand and exercise managed access principles at a nuclear weapons facility. • Exercise the process by which information needed to support detailed discussions regarding a potential monitoring and verification agreement could be gained under managed access conditions. • Assess the impact of the visit on operational security and international nonproliferation obligations.	Obtain, during an unclassified managed access visit, the information needed to develop a monitoring protocol to verify the removal of 200 "Pit Xs" from "System X" and their placement into monitored storage.
Objectives	• From the host team perspective: Show the visitors aspects of the facilities and operations that would demonstrate consistency with their declared purpose without compromising sensitive information. • From the visitors' perspective: Learn as much as possible about the facilities and operations and identify any errors committed by the host, within the guidelines established for the exercise.	For the inspecting party to obtain the information required to reach agreement with the host on inspection and diagnostic methodologies to enable them to demonstrate compliance with the bilateral agreement at a suitable level of confidence by: • Assessing the route that "Pit X" takes through the facility in order to understand the nature and layout of the buildings and the processes involved to ensure no diversions were possible. • Establishing where verification equipment could be placed at key monitoring locations to confirm the process and to monitor components and materials so that "cheating" scenarios could be mitigated. • Building confidence that the facility is actually dismantling "Pit X" in accordance with the agreement.
Results	• Provided an excellent starting point to identify and begin further exploring key managed access issues. • Demonstrated that a managed access approach could facilitate inspections inside sensitive nuclear warhead facilities while protecting sensitive information. • Highlighted the need to develop a holistic approach to monitoring. • Paved the way for developing specific technologies and chain-of-custody procedures.	• Emphasized the importance of: » Preparations for off-normal events. » Tight security, including pre- and post-access security screening measures. » Clear understanding of on-site chain of command. • Helped identify differences between U.S. and U.K. facility safety and security measures, priorities, constraints and access philosophies. • Demonstrated that with careful application of managed access concepts, it was possible in principle to grant controlled access to the necessary facilities and processes while protecting sensitive information.



AWE Burghfield Weapons Facility

	PG Exercise September 2008 Burghfield Weapons Facility, U.K.	**Warhead Monitored Dismantlement (WMD) Exercise** November 2011 Burghfield Weapons Facility, U.K.
	Provide confidence that Country A's declared items of interest (two different types of warheads—a uranium-based warhead and a plutonium-based warhead) were as declared and that they were being dismantled according to the terms of a hypothetical agreement.	Two fictional countries with nuclear weapons negotiate an agreement and protocol that contains basic provisions for mutual nuclear weapon reductions to be accomplished through monitored dismantlement.
	Develop, implement and practice chain-of-custody and confidence-building measures at a nuclear weapons facility.	Prepare for and perform a monitored dismantlement in an operational nuclear facility using a high-fidelity mock-up of a representative nuclear device with actual fissile material and simulated high explosives.
	• Employ radiation measurement and information barrier concepts and techniques. • Analyze acquired measurement data. • Within a host facility: » Use digital photography. » Use change detection. » Create a monitoring party workspace.	• Conduct more realistic monitoring and verification elements than previous joint exercises to enable a deeper understanding of the challenges and issues involved. • Negotiate an agreement and prepare implementing documents, including specific dismantlement monitoring procedures. • Test new and existing equipment and methodologies. • Develop successful methodologies to address key aspects of monitored dismantlement. • Implement a full chain-of-custody regime for the monitored dismantlement of a device containing actual fissile materials. • Implement equipment authentication procedures. • Generate framing documents that could be used in future exercises. • Identify technologies and methodologies for further development.
	• Struck a balance between realism and necessary artificialities in the areas of negotiation dynamics and issues, inspection tools and practices and dismantlement operations, while enabling participants to gain important insights into a negotiation process, the realities of carrying out inspections over an extended (two-week) visit and the difficulties of carrying out monitored dismantlement operations in a working nuclear weapons facility. • Demonstrated the benefits of standardizing monitoring measures, such as image alignment tools for baseline and inspection images of tags and seals. • Highlighted the importance of documenting inspection procedures before the exercise to minimize on-the-spot decision making out of role, thereby minimizing exercise artificiality. • Highlighted the necessity of careful information exchanges between monitoring teams across monitoring shifts.	• Reinforced that countries can successfully collaborate on sensitive technical disarmament and verification topics. • Drew attention to the conflict inherent in seeking to preserve both host party equipment certification and monitoring party equipment authentication. • Demonstrated that a well-managed technical collaboration can facilitate: » Increased understanding for protecting classified and sensitive unclassified information. » Determining the technologies, skills and techniques that are available and can be used to effectively monitor the nuclear weapons reduction process. » Expanding the technical and procedural knowledge base for warhead dismantlement and transparency, as well as monitoring methods in general. » Gaining real-world experience using the potential methods and technologies available.

Joint Measurement and Data Analysis

Jointly demonstrating and analyzing technologies to evaluate their application for potential nuclear warhead monitoring and verification is an essential element of the arms control and nonproliferation cooperation between the United Kingdom and United States.

Over the course of several joint measurement and data analysis events, the United Kingdom and the United States have found that while a number of techniques are able to confirm certain attributes of objects presented in sealed containers, no single technology so far has been able to confirm all of the attributes that could be declared as part of a nuclear weapons monitoring and verification regime.

Joint Measurement Campaign

Immediately after the initial U.S.-U.K. meeting in October 2000, the United Kingdom identified a unique opportunity for U.S. experts to demonstrate various radiation measurement techniques for warhead verification in conjunction with an ongoing warhead dismantlement program. At the same time, the United Kingdom demonstrated complementary approaches. This first Joint Measurement Campaign, conducted in April 2001, included measurements on warheads and warhead components using active and passive measurement techniques, such as high-purity germanium gamma detection, autoradiography, neutron multiplicity counting and the Oak Ridge National Laboratory's Nuclear Material Identification System (NMIS). It provided a substantive starting point for further targeted joint measurements, analysis, research and development.

U.K. and U.S. specialists prepare for a series of measurements during the Joint Diagnostics Exercise, held at the U.K.'s Atomic Weapons Establishment in 2003.

Joint Diagnostics Exercise and Follow-On Neutron Data Analysis Workshop

As a follow-on to the 2001 measurements, U.S. and U.K. measurement experts met in March 2003 to conduct a subsequent series of measurements on classified U.K. objects utilizing a broader set of U.S. and U.K. measurement technologies developed across the U.S. National Laboratories and at AWE, including Brookhaven National Laboratory's Controlled Intrusiveness Verification Technology (CIVET), Sandia National Laboratories' Trusted Radiation Identification System (TRIS) and Trusted Radiation Attribute Demonstration System (TRADS) for fissile material attribute and template measurements, Pacific Northwest National Laboratory and AWE autoradiography, Oak Ridge National Laboratory's NMIS and several Los Alamos National Laboratory and AWE neutron measurement techniques.

In June 2004, U.S. and U.K. experts met at Brookhaven National Laboratory to discuss the results of the 2003 Joint Diagnostics Exercise. Workshop participants also reviewed techniques for neutron measurements of warheads, components, sub-assemblies and sealed containers holding fissile material. The power of active neutron interrogation methods for monitored dismantlement and monitored storage applications was recognized, particularly for fissile material in shielded configurations. However, operation of active neutron interrogation methods is challenging in areas where rigorous dose limits apply because the radiation fields produced by the equipment demand shielding and personnel exclusion areas. As a result, approved use of active neutron methods in U.S. and U.K. nuclear weapon facilities is limited and the practical application of these methods has only been partially explored.

By combining multiple technologies, however, it is possible to construct very robust monitoring and verification approaches that confirm a wide range of potential attributes, particularly if active interrogation techniques are included in the set of measurement technologies applied. However, the potential to release classified information as a consequence of these techniques has to be carefully considered.

Brief descriptions of joint measurement and data analysis events are below. The table that follows provides additional detail and comparative information regarding measurement objectives, techniques employed and outcomes.

Rocky Ridge

In June 2005, U.S. and U.K. experts convened at Lawrence Livermore National Laboratory for a joint measurement campaign dubbed Rocky Ridge where a series of measurements was conducted on classified and unclassified U.S. objects using U.S. and U.K. equipment. Data from all measurements were made available to all participants and the analysis methods and results were discussed extensively. To help consider the results within the context of a potential monitoring regime, subsequent to the discussion of conclusions about each item, a set of arms control-type declarations was presented to the teams. For each declaration and item measured, the group reached consensus on whether the measurement results were consistent with the declaration, inconsistent with the declaration, or neutral (i.e., “cannot tell” from the measurements performed). After the attribute and declaration conclusions had been discussed, the actual details of each item (ground truth) were presented and discussed. Attributes of special nuclear material assemblies including weapon components, data, analysis methods and inferences were discussed.

Scientists from Los Alamos National Laboratory conduct “blind” neutron measurements of an unidentified inspection object at the June 2005 Rocky Ridge campaign.

POTENTIAL MEASUREMENTS FOR WARHEAD DISMANTLEMENT CONFIRMATION

For the purposes of verification research and development, warhead dismantlement has been defined as the separation of a warhead’s fissile material (FM) from its high explosives (HE). In the simplest model, a warhead begins the dismantlement process in a single container that contains both FM and HE and exits the process in two containers: one that contains FM but no HE and a second that contains HE but no FM. Five potential measurements have been posited to support dismantlement confirmation:

1) to confirm the presence of FM in the “FM” container

2) to confirm the absence of HE in the “FM” container

3) to confirm the presence of HE in the “HE” container

4) to confirm the absence of FM in the “HE” container

5) to confirm that all of the FM is in the “FM” container

These measurements can be divided into three categories—each with its own considerations.

Presence in a container: The first and third measurements, to confirm the presence of material in the expected container, are the most straightforward. In a presence measurement the existence of a signal above an agreed threshold can be taken as evidence that the material is present. However, such measurements by themselves only confirm that there is some material where it is supposed to be and are thus not definitive that all material is where it is supposed to be.

Absence in a container: Due to shielding and other considerations, the lack of a measurement signal cannot be taken as proof that the material in question is not present, but it can provide significant confidence. These “absence” measurements, although more complex than the “presence” measurements, are more directly indicative that there is no material where it should not be.

All FM: The fifth measurement is potentially the most definitive and potentially the most difficult. Two approaches have been suggested for this measurement. The first approach (inferential) is to look for FM everywhere else (leaving the room, still in the room, in the HE container). This approach is commonly suggested since it uses existing measurement techniques. Unfortunately this approach relies on one’s ability to measure (and define) “everywhere”—a more complex problem than a specific container measurement. The second approach (direct measurement) is to show that all of the FM from the incoming warhead is contained in the exiting FM container. This approach depends on measurement technology which is not fully developed, but could significantly reduce (or even eliminate) the need for “everywhere” measurements.

A pair of measurements, confirming that all the FM was in the “FM” container (measurement 5) and that no HE was in the “FM” container (measurement 2) may also be sufficient to demonstrate warhead dismantlement.

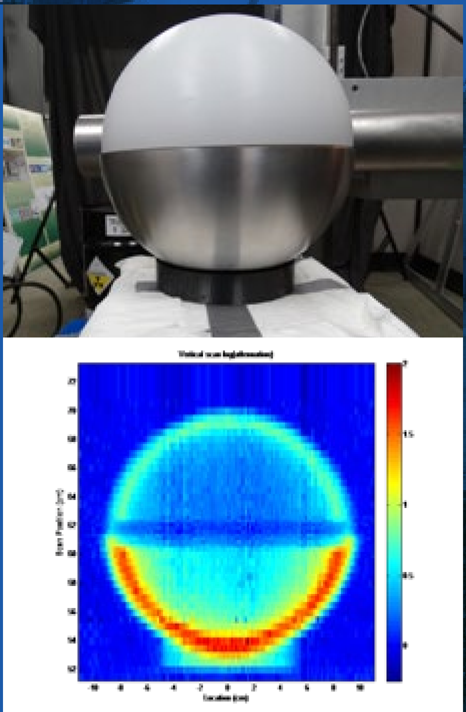
Active Measurement Campaign

Over the course of the first several measurement campaigns and intervening collaborative initiatives, considerable research had been devoted to developing active interrogation technologies to overcome shielding and radiation environment challenges that may be present during potential treaty-related measurements. In September 2010, an Active Measurement Campaign hosted by the Idaho National Laboratory was designed to assess the performance of five potentially verification-applicable, active interrogation technologies. The measurement technologies used for this campaign included the Fission Meter, NMIS, an array of Photonuclear Neutron Detectors provided by Idaho National Laboratory, Pacific Northwest National Laboratory's Optically Stimulated Luminescence Autoradiography, and an AWE array of gamma and neutron detectors to enable pulse-count, pulse-height and pulse-shape data analyses. Questions posed for the campaign included: What types of detectors work best with different sources? How well and how fast can active interrogation provide useful information? The campaign reinforced the value of active interrogation measurements while highlighting the necessity of matching techniques with the appropriate interrogation sources.

An Oak Ridge National Laboratory scientist prepares to conduct a measurement using the NMIS during the 2010 Active Measurement Campaign, held at the Idaho National Laboratory.

THE NUCLEAR MATERIAL IDENTIFICATION SYSTEM

The Nuclear Material Identification System (NMIS) developed by Oak Ridge National Laboratory has proven particularly effective at confirming multiple declared attributes of objects in sealed containers. The most effective use of NMIS requires active interrogation with a time and direction-correlated neutron source using an accelerator-based neutron generator. While both passive and active use of NMIS have been approved for nuclear weapon components, active interrogation techniques can present additional radiation challenges that require mitigation to ensure the lowest possible levels of radiation exposure to personnel.



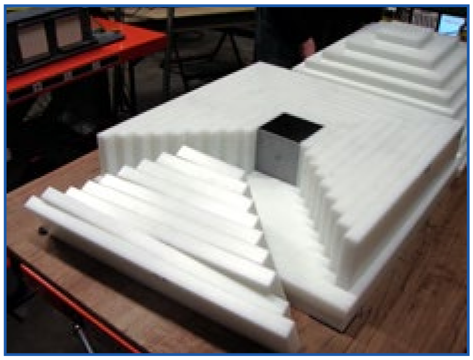
NMIS neutron tomographic imaging example using a simple test object with a 0.5" polyethylene upper and 0.5" steel lower shell.

Idaho National Laboratory (Materials and Fuels Complex)

MG Campaigns

AWE hosted a series of exercises designated “MG” from 2013–2014. MG 1, held in 2013, used U.S. and U.K. technologies for a series of measurements on the high-fidelity mock-up used during the 2011 WMD Exercise to provide further insight into the WMD Exercise results, as well as to generate benchmarking data and study container and configuration effects on algorithms.

MG 3 (MG 2 was a U.K. activity only), held in 2014, employed the same detectors used in MG 1 in addition to a gamma radiation imaging system and two miniature, low-power detection systems. In these measurements, the fissile material was configured into multiple geometries and measured without surrounding moderators.



A moderating pyramid used to test measurement equipment during the MG Campaigns.

A U.S. scientist demonstrates TRIS on a warhead storage container.

TRIS AND TRADS

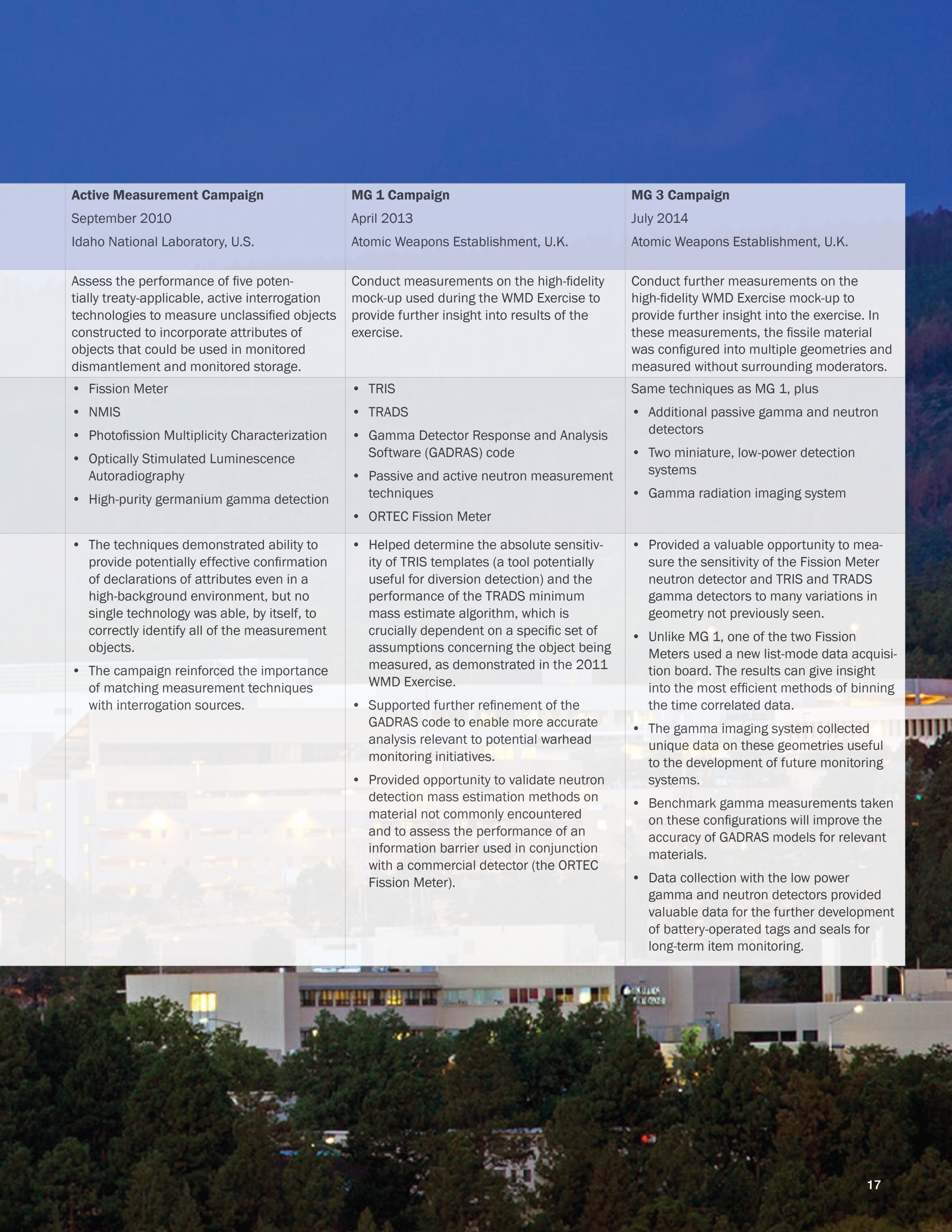
The Trusted Radiation Identification System (TRIS) and the Trusted Radiation Attribute Demonstration System (TRADS) are radiation measurement systems developed at Sandia National Laboratories that both use a Trusted Processor (TP) to protect sensitive information while making verification measurements. The TP is a computer housed within a tamper indicating steel enclosure with an internal Information Barrier that isolates classified information from the unclassified output. TRIS and TRADS have been deployed during several joint U.S.-U.K. measurement campaigns and exercises.

TRADS was originally developed in 1999 to perform radiation attribute measurement and analysis, determining the isotopic composition of plutonium-bearing components and the minimum mass for the isotope ^{239}Pu. The system reports only whether an item is consistent with declared attributes and provides no further information.

TRIS was first developed in 2001 to provide a means for confirming the identities of accountable items by comparing gamma-ray spectral measurements, a technique known as template matching. Matching the radiation spectrum of an accountable item to a reference template increases inspector confidence when monitoring a process with many identical accountable items and is much faster than most attribute measurements. The Next-Generation TRIS was developed in 2010, and it uses a Trusted Multi-Channel Analyzer (MCA) located within the TP housing, in comparison to the First-Generation TRIS, which used a commercial MCA external to the TP.

Table 2: Summary of Joint Measurement and Data Analysis

Exercise	**Joint Measurement Campaign** April 2001 Atomic Weapons Establishment, U.K.	**Joint Diagnostics Exercise** March 2003 Atomic Weapons Establishment, U.K.	**Rocky Ridge** June 2005 Lawrence Livermore National Laboratory, U.S.
Situation	Demonstrate various potential radiation measurement techniques for warhead and fissile material verification in conjunction with an ongoing warhead dismantlement program.	Conduct "blind" measurements on unknown target objects in sealed containers to help move beyond proof of principle and establish a basis for further investigation and utilization of specific measurement techniques.	Conduct "blind" measurements on classified and unclassified U.S. objects.
Measurement and Data Analysis Techniques Employed	• High-purity germanium gamma detection • Autoradiography • Neutron multiplicity counting • NMIS	• CIVET • TRIS • TRADS • Autoradiography • NMIS • Several neutron measurement techniques	• Pinhole camera autoradiography • "Venetian blind" autoradiography • Neutron correlation techniques • Detectors based on a new scintillator material
Outcomes	• Provided a substantive starting point for further targeted joint measurements, analysis, research and development. • Demonstrated that U.S. and U.K. experts could cooperate effectively in challenging technical environments. • Confirmed that active and passive radiation detection measurements can provide information of potential value in a warhead- and fissile material-based monitoring or verification regime.	• CIVET, TRIS, TRADS, NMIS and the various neutron measurement techniques all demonstrated capabilities that could be of significant value in future monitored dismantlement applications. • The importance of careful background measurements in an active nuclear facility was highlighted.	• Each measurement technique was able to confirm certain attributes of the objects presented in sealed containers, but no single technology was able to confirm all of the declared attributes.



Active Measurement Campaign September 2010 Idaho National Laboratory, U.S.	**MG 1 Campaign** April 2013 Atomic Weapons Establishment, U.K.	**MG 3 Campaign** July 2014 Atomic Weapons Establishment, U.K.
Assess the performance of five potentially treaty-applicable, active interrogation technologies to measure unclassified objects constructed to incorporate attributes of objects that could be used in monitored dismantlement and monitored storage.	Conduct measurements on the high-fidelity mock-up used during the WMD Exercise to provide further insight into results of the exercise.	Conduct further measurements on the high-fidelity WMD Exercise mock-up to provide further insight into the exercise. In these measurements, the fissile material was configured into multiple geometries and measured without surrounding moderators.
• Fission Meter • NMIS • Photofission Multiplicity Characterization • Optically Stimulated Luminescence Autoradiography • High-purity germanium gamma detection	• TRIS • TRADS • Gamma Detector Response and Analysis Software (GADRAS) code • Passive and active neutron measurement techniques • ORTEC Fission Meter	Same techniques as MG 1, plus • Additional passive gamma and neutron detectors • Two miniature, low-power detection systems • Gamma radiation imaging system
• The techniques demonstrated ability to provide potentially effective confirmation of declarations of attributes even in a high-background environment, but no single technology was able, by itself, to correctly identify all of the measurement objects. • The campaign reinforced the importance of matching measurement techniques with interrogation sources.	• Helped determine the absolute sensitivity of TRIS templates (a tool potentially useful for diversion detection) and the performance of the TRADS minimum mass estimate algorithm, which is crucially dependent on a specific set of assumptions concerning the object being measured, as demonstrated in the 2011 WMD Exercise. • Supported further refinement of the GADRAS code to enable more accurate analysis relevant to potential warhead monitoring initiatives. • Provided opportunity to validate neutron detection mass estimation methods on material not commonly encountered and to assess the performance of an information barrier used in conjunction with a commercial detector (the ORTEC Fission Meter).	• Provided a valuable opportunity to measure the sensitivity of the Fission Meter neutron detector and TRIS and TRADS gamma detectors to many variations in geometry not previously seen. • Unlike MG 1, one of the two Fission Meters used a new list-mode data acquisition board. The results can give insight into the most efficient methods of binning the time correlated data. • The gamma imaging system collected unique data on these geometries useful to the development of future monitoring systems. • Benchmark gamma measurements taken on these configurations will improve the accuracy of GADRAS models for relevant materials. • Data collection with the low power gamma and neutron detectors provided valuable data for the further development of battery-operated tags and seals for long-term item monitoring.

Focused Experts’ Workshops and Meetings

Managed access exercises and joint measurement campaigns have provided several opportunities to test and evaluate measurement techniques and potential approaches for enabling warhead and dismantlement confirmation at sensitive nuclear facilities. To complement this body of work, the United Kingdom and the United States have conducted a series of focused experts’ workshops and meetings to delve deeper into specific aspects of verification. These experts’ workshops and meetings have allowed U.S. and U.K. experts to develop a much deeper understanding of specific issues and collaborate to advance understanding and capabilities between specific exercises.

Sandia National Laboratories

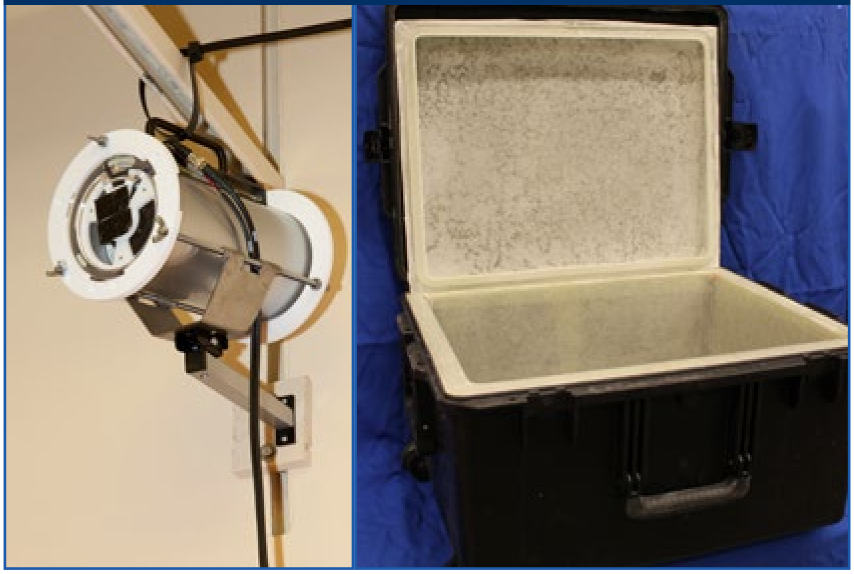
Chain-of-Custody Exchanges

An active program of joint U.S.-U.K. cooperation on issues and technologies associated with chain of custody, including tags, seals, tamper indicating devices (TIDs) and tamper indicating enclosures (TIEs), began with a kickoff workshop at Pacific Northwest National Laboratory in April 2006 and has continued with a series of frequent technical visits and working meetings to U.S. and U.K. facilities in the ensuing years. The focus of the first workshop included discussing historical development, evolution and experience with different tags and seals (e.g., the Reflective Particle Tag, the Ultrasonic Intrinsic Tag and fiber-optic based tamper indicating devices). This workshop provided U.S. and U.K. experts with an opportunity to work side-by-side to assess and gain valuable experience through laboratory demonstrations and hands-on experimentation using various unique identification and tamper indicating technologies.

The series of chain-of-custody technical exchanges and experts' meetings have continued since the initial TID/TIE Workshop to examine standard operating procedures for different TID and TIE technologies, operational and environmental constraints and potential applications for arms control and to explore and evaluate novel TID and TIE techniques, including use of fiber optics and advanced unique identifiers (UID) and TID technologies.

TAMPER INDICATING ENCLOSURES

Following the PG Exercise and in preparation for future exercises, the United States and United Kingdom increased their focus on developing tamper indicating enclosures (TIEs) for deployed monitoring equipment: the United Kingdom focused on the Wide Area Monitoring Camera (WAMCAM) for video surveillance and the United States focused on TIEs utilizing Pacific Northwest National Laboratory's fiber optic smart container expertise. Versions of each were used during the 2011 WMD Exercise, and U.S. and U.K. participants presented observations and conclusions as well as thoughts on future directions during the Exercise Hot Wash. A result of the Hot Wash was a consensus list of topics for further evaluation and development, including further work on TIEs.



WAMCAM is shown on the left. A concept for a fiber optic insert for a TIE is shown on the right.

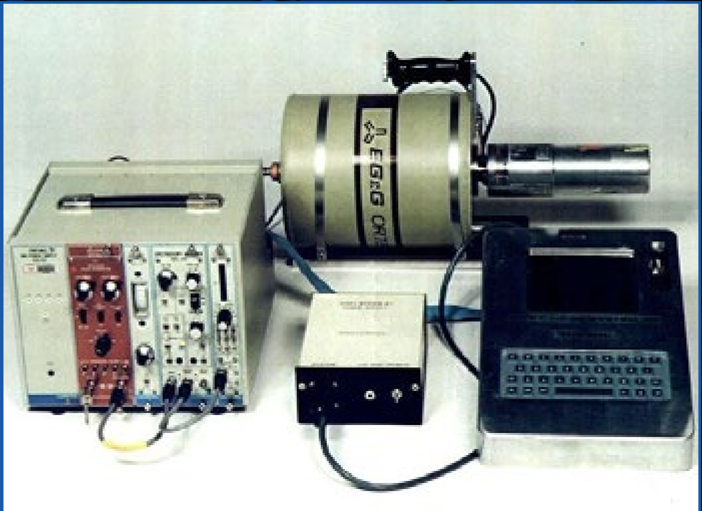
Information Barrier Workshop

The ability to protect classified and unclassified sensitive information during measurements conducted for warhead chain of custody and confirmation of declarations is essential for monitored dismantlement and monitored storage regimes. U.S. and U.K. experts met at Los Alamos National Laboratory in April 2007 to discuss the information barrier approach to the protection of sensitive information. Previous approaches to information protection using information barriers and general principles of information barriers were reviewed and potential new approaches to information protection were discussed. The results of the workshop guided the thinking of exercise planners and participants throughout the major exercises conducted in the 2008–2011 timeframe.

Workshop participants reviewed information barrier technology development and explored the possibilities for future U.S.-U.K. collaboration in this area. The group discussed the integrated information barrier and radiation measurement system technology concept as it might be used to support warhead or fissile material component verification. Workshop participants explored how an information barrier could provide useful output during a verification regime; specifically, how information barrier technologies might be used to confirm nuclear attributes of classified items while protecting classified and sensitive unclassified information, and how to validate the functionality of such a system. Both sides came away with a deeper understanding of the challenge of information protection during classified measurements. A number of issues that had been polarizing in early information barrier work (e.g., commercial versus custom technologies) were determined to be much more complex and nuanced than previously recognized. The workshop resulted in a much greater understanding of the subtleties of the issues—especially when the needs of two parties (a host and a monitor) must be considered.

CIVET (CONTROLLED INTRUSIVENESS VERIFICATION TECHNOLOGY) – AN EARLY MEASUREMENT SYSTEM WITH AN INFORMATION BARRIER.

Brookhaven National Laboratory's CIVET system provided very precise matching of radiation templates consisting of the intensities of high resolution gamma lines emanating from special nuclear materials. The system compared several objects and showed which ones were identical. Such measurements and analysis were performed using a simple microprocessor, with open code, designed to be easily certified and authenticated. This approach assumed that (a) an initial template could be obtained by measurement of an object known to be genuine (e.g., a deployed weapon on a delivery system), (b) the information in the template could be protected by dual-key encryption so that it could not be revealed to, or modified by, either party and (c) the executable software was checked by dual keys during operation. In principle, the same hardware could have been used with other software to evaluate attributes.



Authentication Workshop (2009)

Authentication is the other side of the information protection coin. While the inspected party must have confidence that its sensitive information is secure, the monitoring party must have confidence that the measurements accurately reflect the attributes of the objects measured, that chain of custody has been maintained, that declarations have been confirmed and that any anomalies have been detected.

U.S. and U.K. experts met at Sandia National Laboratories in March 2009 for the first of two workshops to discuss aspects of the authentication problem. The first Authentication Workshop served as an information exchange between the United States and the United Kingdom and facilitated interaction among each side's participants. This workshop focused primarily on technologies rather than the broader issues associated with the application of technologies within a particular monitoring and verification regime. Many of the technologies discussed were directly applicable to the challenge of enabling authentication, though several were determined to be less applicable than had been expected. The workshop also helped illuminate that "authentication" as a concept means different things to different communities. For example, even within an international safeguards context, which is expected to have a similar viewpoint to the arms control community, it was shown that there are different concerns and priorities.

AUTHENTICATION VS. CERTIFICATION

Authentication: A process by which a monitoring party to a treaty or agreement obtains confidence that the information reported by the monitoring equipment accurately reflects the true state of a monitored item and that the monitoring equipment has not been altered, removed, or replaced and functions such that it provides accurate and reproducible results at all times.

Certification: A process by which a monitored party to a treaty or agreement assures itself that an inspection/monitoring system meets required safety and security requirements and will not divulge classified or proliferative information to a monitoring party.

An important objective of U.S.-U.K. cooperation has been to understand the requirements for equipment certification and authentication and how it may be possible to both certify and authenticate equipment and measurement results.

Monitored Storage Visit

In February 2010 Sandia National Laboratories hosted a Monitored Storage Visit to investigate the principles of monitored storage for warheads, criteria for the development of storage monitoring techniques and methods to assess their robustness. Participants discussed a range of possible technical solutions to the monitored storage problem and visited the mock-up monitored storage facility in the Sandia technical area. Several of the approaches discussed were incorporated into the 2011 WMD exercise. A key question posed during the visit—and a continued focus of U.S.-U.K. cooperative research—was, "What level of monitoring is required to provide confidence?" Participants recognized the potential for complex systems to generate difficulties for a long-term monitoring / verification system, so simplicity in design is an essential principle. U.K. participants previewed work on modeling initiatives they were pursuing to help determine system requirements and effectiveness.

Authentication Workshop (2014)

Realizing the importance of the authentication problem, a second U.S.-U.K. Authentication Workshop was held at Sandia National Laboratories in 2014 to review the lessons learned from the intervening major exercises and to consider the path forward for incorporating authentication and certification principles early in the design process for future equipment, procedures and monitoring regimes. The 2014 Authentication Workshop focused on the application of authentication techniques to specific treaty verification problems. For this workshop, the term "authentication" was defined explicitly from a treaty verification perspective and all of the discussed techniques were evaluated from this point of view. There was much more emphasis during this workshop on ascertaining, with regard to the body of authentication work that had been completed since 2009, what had worked, what had not worked and what could be done better. The 2011 WMD Exercise provided for many specific examples. Building from this experience, workshop participants sought to build areas of consensus rather than simply exchanging information. The concept of joint equipment development as a way to enable authentication was discussed extensively. The joint U.S.-U.K. Portal Monitor for Arms Control (PMAC) project is a joint development to accomplish simultaneous host certification and monitor authentication and provides the opportunity to develop and apply key learning points from the 2014 Authentication Workshop.

BUNKER SITE

Sandia National Laboratories' Monitored Storage/Chain of Custody Engineering Test Bed (Bunker Site) consists of two replica munitions storage bunkers. This site was used during the 2010 Monitored Storage Visit to demonstrate intrusion detection and warhead monitoring technologies and to stimulate further U.S.-U.K. discussions on these topics. These discussions included the types and architecture of monitoring sensors, system evaluation and testing and vulnerability analysis, including consideration of the insider threat. Current activities at this site are focused on engineering development of sensor systems for warhead monitoring in a representative environment.

The outside and inside of Sandia National Laboratories' demonstration bunker, shown with representative mock objects for demonstration purposes.

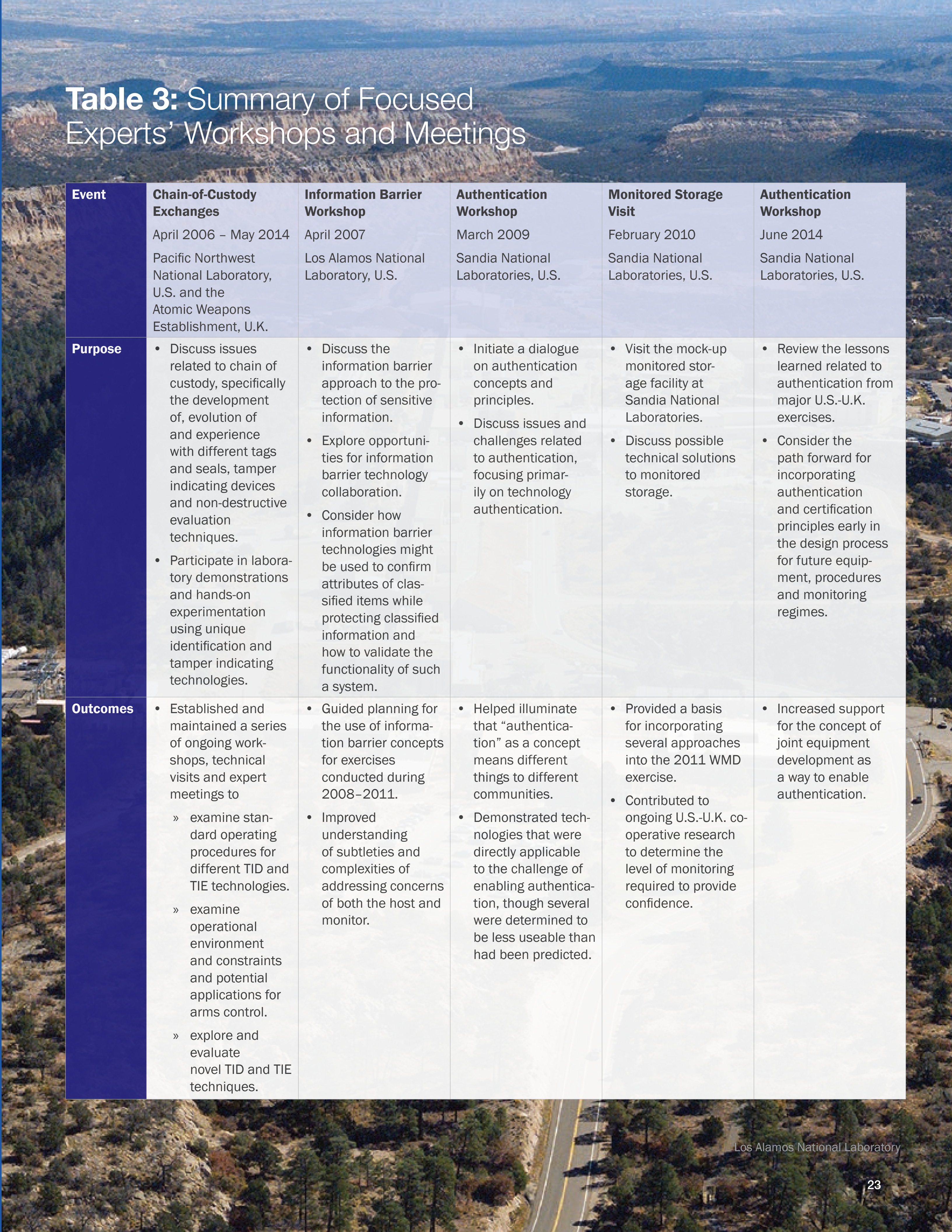


Table 3: Summary of Focused Experts' Workshops and Meetings

Event	**Chain-of-Custody Exchanges** April 2006 – May 2014 Pacific Northwest National Laboratory, U.S. and the Atomic Weapons Establishment, U.K.	**Information Barrier Workshop** April 2007 Los Alamos National Laboratory, U.S.	**Authentication Workshop** March 2009 Sandia National Laboratories, U.S.	**Monitored Storage Visit** February 2010 Sandia National Laboratories, U.S.	**Authentication Workshop** June 2014 Sandia National Laboratories, U.S.
Purpose	• Discuss issues related to chain of custody, specifically the development of, evolution of and experience with different tags and seals, tamper indicating devices and non-destructive evaluation techniques. • Participate in laboratory demonstrations and hands-on experimentation using unique identification and tamper indicating technologies.	• Discuss the information barrier approach to the protection of sensitive information. • Explore opportunities for information barrier technology collaboration. • Consider how information barrier technologies might be used to confirm attributes of classified items while protecting classified information and how to validate the functionality of such a system.	• Initiate a dialogue on authentication concepts and principles. • Discuss issues and challenges related to authentication, focusing primarily on technology authentication.	• Visit the mock-up monitored storage facility at Sandia National Laboratories. • Discuss possible technical solutions to monitored storage.	• Review the lessons learned related to authentication from major U.S.-U.K. exercises. • Consider the path forward for incorporating authentication and certification principles early in the design process for future equipment, procedures and monitoring regimes.
Outcomes	• Established and maintained a series of ongoing workshops, technical visits and expert meetings to » examine standard operating procedures for different TID and TIE technologies. » examine operational environment and constraints and potential applications for arms control. » explore and evaluate novel TID and TIE techniques.	• Guided planning for the use of information barrier concepts for exercises conducted during 2008–2011. • Improved understanding of subtleties and complexities of addressing concerns of both the host and monitor.	• Helped illuminate that "authentication" as a concept means different things to different communities. • Demonstrated technologies that were directly applicable to the challenge of enabling authentication, though several were determined to be less useable than had been predicted.	• Provided a basis for incorporating several approaches into the 2011 WMD exercise. • Contributed to ongoing U.S.-U.K. cooperative research to determine the level of monitoring required to provide confidence.	• Increased support for the concept of joint equipment development as a way to enable authentication.

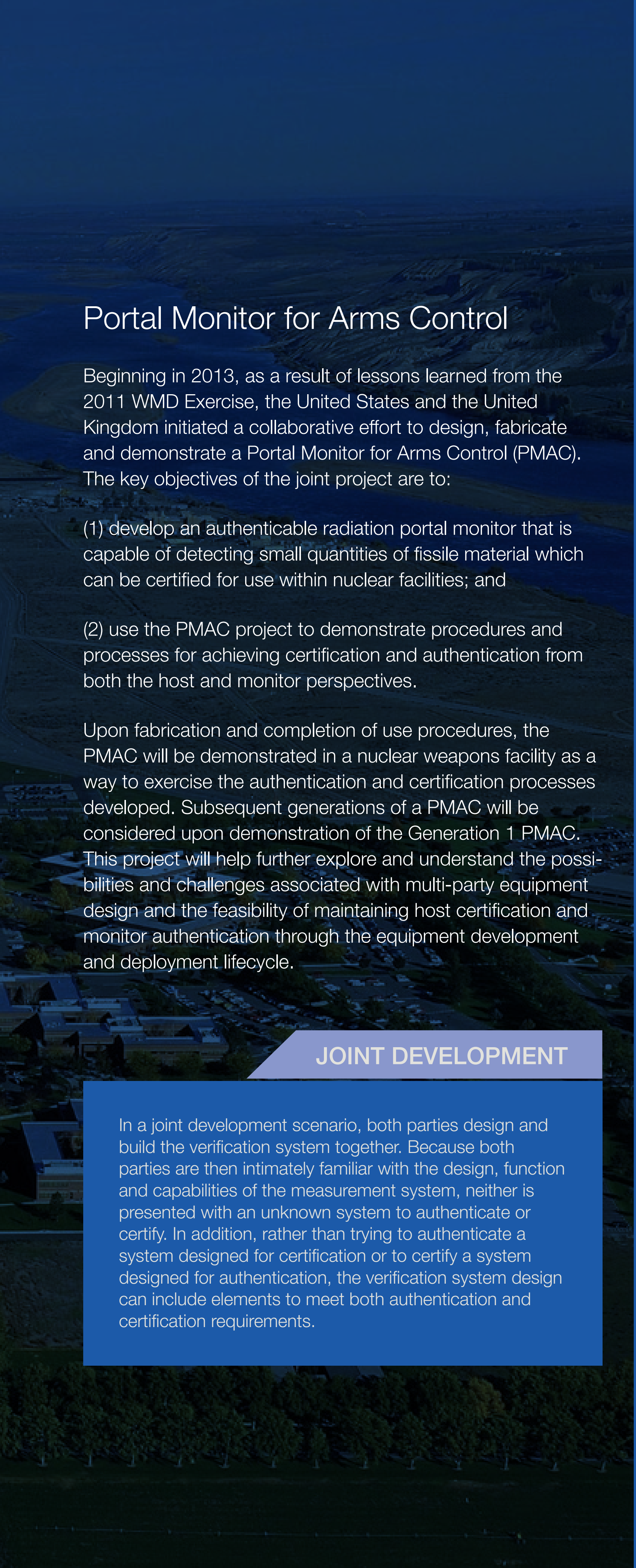
Current Research

Building on the success of the exercises, measurement campaigns and workshops held over the past 15 years, cooperation between the United Kingdom and the United States is continuing. Currently, the countries are focused on two significant joint initiatives: completing and archiving data from the Warhead Measurement Campaign and the development and demonstration of a Portal Monitor for Arms Control.

Warhead Measurement Campaign and Comprehensive Data Set Development

Since 2012, the United States, with the assistance of the United Kingdom, has been executing an integrated modeling and measurement campaign to establish a comprehensive signature set of nuclear warheads and components. The resulting data and modeling capability will support assessment of both the efficacy and limitations of potential future warhead reduction treaty verification technologies. The campaign will guide future research and development in the areas of measurements for warhead verification and information protection. This radiation signature set will be of enduring value for arms control, nonproliferation and other national security purposes. The United Kingdom is an active participant in this campaign, cooperating with the United States to complete measurement planning and helping ensure data documentation, measurement and results validation, data archiving and accessibility.

A B53 Nuclear Explosive-Like Assembly, or NELA, was the first object measured by the Warhead Measurement Campaign. It is shown here during an imaging measurement at the Pantex Plant being performed by Oak Ridge National Laboratory. A NELA is a high fidelity mock-up of a nuclear warhead with substitute materials. The B53 9-megaton gravity bomb was one of the highest yield nuclear weapons ever fielded by the United States. The last B53 was dismantled by the United States in 2011.



Portal Monitor for Arms Control

Beginning in 2013, as a result of lessons learned from the 2011 WMD Exercise, the United States and the United Kingdom initiated a collaborative effort to design, fabricate and demonstrate a Portal Monitor for Arms Control (PMAC). The key objectives of the joint project are to:

(1) develop an authenticable radiation portal monitor that is capable of detecting small quantities of fissile material which can be certified for use within nuclear facilities; and

(2) use the PMAC project to demonstrate procedures and processes for achieving certification and authentication from both the host and monitor perspectives.

Upon fabrication and completion of use procedures, the PMAC will be demonstrated in a nuclear weapons facility as a way to exercise the authentication and certification processes developed. Subsequent generations of a PMAC will be considered upon demonstration of the Generation 1 PMAC. This project will help further explore and understand the possibilities and challenges associated with multi-party equipment design and the feasibility of maintaining host certification and monitor authentication through the equipment development and deployment lifecycle.

JOINT DEVELOPMENT

In a joint development scenario, both parties design and build the verification system together. Because both parties are then intimately familiar with the design, function and capabilities of the measurement system, neither is presented with an unknown system to authenticate or certify. In addition, rather than trying to authenticate a system designed for certification or to certify a system designed for authentication, the verification system design can include elements to meet both authentication and certification requirements.

Next Steps

The United Kingdom and the United States look forward to building on the extensive body of research and analysis completed during the first 15 years of joint U.S.-U.K. technical collaboration on nuclear disarmament verification. Work to date provides an essential basis for advanced equipment development and integration of technologies and methodologies into more complete and robust regimes for future exercise and evaluation. This work has also highlighted gaps in existing capabilities and areas where further research is necessary, including in the areas of data authentication, fissile material detection and sensitive information protection. The United Kingdom and the United States are committed to advancing this body of international research in support of future international initiatives and meeting shared obligations under Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons.

OFFICE OF
NONPROLIFERATION AND
ARMS CONTROL (NPAC)

Ministry
of Defence

United States Department of Energy
National Nuclear Security Administration
Defense Nuclear Nonproliferation
Office of Nonproliferation and Arms Control
(Formerly the Office of Nonproliferation and International Security)
1000 Independence Avenue, S.W.
Washington, D.C. 20585
www.nnsa.energy.gov/nonproliferation/nis

Cover: A close-up of "Inspection Object 7" inside its storage container during the Active Interrogation Joint Measurement Campaign at Idaho National Laboratory in 2010. Several identified and unidentified radioactive sources were used throughout the campaign to test different measurement and analysis techniques.
Top Left: A U.S. monitor under U.K. escort inspects the integrity of seals placed on a temporary barrier erected to support dismantlement activities during the 2011 Warhead Monitored Dismantlement Exercise. This barrier supported the "room within a room" concept for monitoring sensitive operations.
Top Right: U.S. and U.K. representatives discuss methods for verification of nuclear disarmament on the margins of the 2014 Preparatory Commission meeting for the 2015 NPT Review Conference.
Background: Oak Ridge National Laboratory.