IV. MONITORING ACTIVITIES AND TECHNOLOGIES

Before embarking on a discussion of the various dismantlement monitoring options, it will be useful to discuss the activities and technologies which can be used as the building blocks of these options. This chapter presents various monitoring activities and technologies that may be useful to the dismantlement monitoring process. The next chapter will then discuss dismantlement options that may be constructed from these activities.

In undertaking this report it is necessary to limit the types of technologies that will be considered. This report takes the position that dismantlement monitoring will be an on-site activity. For this reason, no consideration has been given to monitoring techniques such as National Technical Means (NTM) which played such a large part in the negotiations of the START I and II Treaties. This is appropriate since the small size of the Treaty Limited Items (TLIs) which are relevant to a warhead dismantlement treaty (nuclear warheads, and warhead components) greatly reduces the usefulness of NTM alone for monitoring treaty compliance. This was also a fundamental conclusion of the President's Report to Congress (the 3151 Report), and the JASON Report (see Appendix C).

As a further constraint on the technologies considered in this report, it was decided to limit consideration to technologies that could be fielded within a year of the completion of a dismantlement treaty. This is not to imply that all of the technologies described below are in a monitoring-ready condition, but that experimental work has been carried out in these areas and prototype systems have been developed and tested.

DECLARATIONS

Declarations form the basis of any warhead dismantlement monitoring regime. Declarations consist of statements, made by the host country, concerning some aspect of its nuclear weapons program. These can range from numbers of warheads available to the host (e.g., "the U.S. has 2750 warheads of a given type"), to information about schedules (e.g., "the U.S. intends to dismantle 27 warheads a week during September"), to information on storage (e.g., "there are 19 individual warheads components, removed from dismantled nuclear warheads, in a particular magazine at Pantex"). Of particular interest for dismantlement monitoring would be declarations of the numbers of warheads declared excess to national needs, declarations of warheads transported to Pantex, declarations of dismantlement rates, declarations of the movement of warheads from Zone 4 to Zone 12 for dismantlement, and declarations of the movement of pits from Zone 12 to Zone 4 or of canned subassemblies from Zone 12 to the Y-12 Plant after dismantlement. These declarations could be unclassified, classified at the Confidential National Security Information (C/NSI) level, or classified at the Restricted Data or Formerly Restricted Data (RD/FRD) level, depending on the content of the declarations and the legal constraints on sharing classified information with the treaty partner.

The declarations will be based on the existing inventory and processing record systems at Pantex and Y-12. It will be necessary to develop the process by which the data to be declared is extracted from the existing record systems. It is anticipated that the overall activity of declarations and data exchanges will be simple, with relatively modest impact and cost. Included within the area of declarations will be the question of process flow initiation. The dismantlement of each individual warhead type at Pantex occurs in a unique manner, with a material flow through the various cells and bays that is specific to that system. It will be necessary to develop specific briefings for inspectors before they can begin to understand and monitor the dismantlement of individual warhead types.

SPOT CHECKS

Declarations are a necessary part of any dismantlement monitoring regime, but are not by themselves sufficient to confirm dismantlement. One method of improving the credibility of declarations is by the introduction of

Spot Check inspections to confirm the declarations. Spot Checks are usually taken to mean the application of random inspections at a few locations to confirm the contents of a set of declarations. These inspections can employ various levels of intrusiveness, from the audit of records to simple item accounting, to verifying unique identifiers on storage containers, to radiation measurements such as those proposed for radiation signatures or MRI inspections. For dismantlement monitoring Spot Checks would be applied in the warhead and component storage areas to confirm that the contents of the magazines matched the declarations.

Whatever the level of intrusiveness, Spot Checks usually imply that the inspection method is only applied at a subset of the possible inspection locations or containers at any one time, but that the locations and containers are chosen by the inspecting party. This is in contrast to methods to be described later in which the inspecting party would apply the same techniques to every item of inspection. At the beginning Spot Checks provide a moderate level of confidence, but with continued application, the level of confidence rises considerably as the statistics improve.

REMOTE MONITORING

Remote monitoring activities for dismantlement monitoring refers to the application of various containment and surveillance technologies to give a level of confidence that events have or have not occurred without the actual presence of inspectors. Cameras are traditionally used to monitor storage areas or perimeters. These can be coupled with anti-intrusion image storage units or satellite links to send the images in real time to remote locations. Tags and seals of various kinds also fall into this area. These can be applied to storage buildings or to individual storage containers to indicate if the items have been tampered with, or to assure the lack of intrusion. Application of such techniques would allow the inspectors to follow the dismantlement activities by watching the movement of warheads and components in and out of the storage area, even when they are not present at the facility.

In order for a remote monitoring system to provide credible information, it would have to be tamper protected. Such systems have been designed and installed to assist the International Atomic Energy Agency (IAEA) in monitoring safeguarded fissile materials. Additional confidence would be offered by systems which were data authenticated and included additional sensors such as motion or seismic sensors and proximity sensors. The major cost of this activity is for equipment and site preparation. This activity should involve minimal impact and inspection cost.

Remote monitoring can be thought of as an extension of surveillance which allows visual images to be seen at a different, perhaps distant location. Currently the U.S. and Russia have a demonstration project to study the application of remote monitoring to spent fuel storage facilities. This project is a joint venture between the Kurchatov Institute and the U.S. Argonne National Laboratory (West). As a result of this project, real-time images of the spent fuel storage facilities at each location are available at the other facility.

A significant question in the remote monitoring area is the ability of tags and seals to either indicate tampering or to assure non-intrusion. Most currently used systems are good enough to always indicate tampering, if one has sufficient time to examine the tag or seal. For current systems used on small containers, such as the ALR8 or AT400 containers, schemes to defeat the containers themselves may be more of a concern than schemes to defeat the tags and seals.

For larger structures, such as the magazines in Zone 4, current systems may be more effective, but again one must consider other scenarios for entry into the structure. The U.S. government has sponsored a wealth of red teaming activities in the general area of tags and seals. Before using these techniques for dismantlement monitoring it would be necessary to evaluate this knowledge in view of the specific applications of interest.

CHAIN-OF-CUSTODY

Chain-of-custody is a technique to provide continuous monitoring of the existence or presence of an accountable item. Chain of custody demonstrates that an unaltered or uninterrupted custody or control of an item has been maintained by the owner or inspector, depending on the monitoring protocol, that provides confidence that deceptions have not been introduced. Specific technologies utilized are tamper indicating devices (TIDs) such as tags and seals, radiation signature measurements, remote monitoring technologies, and direct observation.

In the case of warhead dismantlement monitoring, chain-of-custody implies that the inspectors would begin to observe the warhead early in the dismantlement flow, at the entrance to Zone 4 at Pantex, or when the warhead is accepted for custody by DOE, or even when it is removed from the delivery vehicle, deployment site, or storage depot at a DOD facility. Through the use of unique identifiers, tags and seals, radiation measurements, and/or physical accompaniment of the Treaty Limited Items and direct observation, the inspectors would be able to follow the exact warhead through the dismantlement procedure to the dismantlement bay or cell at Pantex. Following the actual dismantlement, the inspectors would be allowed to follow the nuclear components to their storage location pending final disposition, either in Zone 4 at Pantex or at the Y-12 facility in Oak Ridge.

The level of intrusiveness that accompanies chain-of-custody depends on the types of measurements that the inspectors are allowed to see and do, and the types of records that they have access to. These measurements could range from reading the unclassified unique identifiers that are already on all U.S. warheads, to unclassified radiation measurements such as the measurement done during reception of CSAs at the receiving facility at Y-12. More intrusive measurements would include the confirmation measurements currently done within 72 hours of reception at Pantex and Y-12, MRI-like measurements, or the types of measurements described below in the discussion of radiation "signature" methods. The ultimate in chain-of-custody would include having the inspectors observe the actual dismantlement, either remotely or directly.

At Pantex, chain-of-custody can be confined to Zone 4, Zone 4 plus the portal of Zone 12, or can be extended all the way to the dismantlement cell and back. Chain of custody within Zone 12 would not be a linear process, since the warhead typically moves back and forth between different dismantlement bays and cells during the course of dismantlement. This non-linear flow is different for each warhead type. The study group concluded, however, that it would be possible to do a chain-of-custody at the C/NSI level but that would not reveal Restricted Data or Formerly Restricted Data. Such a chain-of-custody could extend all the way to the dismantlement cell and back to the storage areas, even though it would be costly and highly intrusive. Coupling such a chain-of-custody with radiation measurements or finger-printing techniques would allow inspectors to follow a warhead and its components from its retirement through dismantlement to storage pending the final disposition of the fissile material.

PORTAL PERIMETER CONTINUOUS MONITORING

PPCM refers to a system for inspecting every item that passes into or out of a specific area. For this activity to be effective, the inspecting party must control all of the access portals to the facility of interest. This usually involves either remote monitoring or actual visual inspection of the entire fence line (or perimeter) surrounding the facility to be monitored. All traffic into and out of the facility is then directed through a single portal, or a small number of portals. The inspectors have the right to stop and examine any item passing through the portal that is big enough to contain a TLI. For warhead dismantlement monitoring, such inspections could be classified or unclassified, depending on the level of information which can be shared with the inspectors.

PPCM is usually thought of as a system that limits the intrusiveness of monitoring TLIs. This is generally true for treaties like START and INF, where the TLIs are very large and can only be contained in a very heavy truck or a rail car. In a dismantlement treaty scenario however, PPCM would be extremely intrusive, because some Treaty Limited Items, e.g., certain nuclear warhead components resulting from dismantlement, could be quite small, and would easily fit in a car trunk, a glove compartment, or under a coat. For a Portal Perimeter Continuous Monitoring regime to be effective it would require permanent presence of an inspection team at the facility being monitored, or the use of remote monitoring techniques. PPCM for small Treaty Limited Items also requires a very thorough initialization procedure to ensure that no items have been sequestered within the monitored area that can be used to mock up the items of inspection and spoof the inspections.

PPCM can be either classified or unclassified, depending on the measurements that the inspectors are allowed to carry out. An unclassified, but still highly intrusive, scenario can be constructed in which the inspectors monitor all items large enough to contain a TLI, but using measurements that only reveal the presence of fissile material.

There are also significant considerations in applying PPCM to an area where many different warhead operations are performed, such as Zone 12 at Pantex. PPCM is only meaningful if all traffic in and out of the area is subject to search and documentation. If all of Zone 12 at Pantex or all of the Western Exclusion Area at Y-12 were placed under PPCM this would subject all refabrication, refurbishing, and retrofit activities for the enduring stockpile to inspections. This would adversely affect the DOE's ability to fulfill the Presidential requirement to maintain a safe, secure, reliable stockpile.

Therefore, the PPCM option would only be viable at Pantex if PPCM is applied to a portion of Zone 12 which is segregated from the rest of Zone 12 and dedicated to the dismantlement of warheads covered by the treaty. By declaration, no dismantlement of warheads covered by the treaty would occur in the rest of Zone 12, and therefore the rest of Zone 12 would not be subject to PPCM. This dedicated dismantlement zone would have to be segregated from the remainder of Zone 12 by a security perimeter sufficient to demonstrate to the inspectors that there was no potential for material to enter the zone other than by the monitored portals. The dedicated portion of Zone 12 would have to be initialized by a thorough one-time search to confirm that the area contains no warheads or components. This would be done, for example, to ensure that there was no clandestine stockpile of pits already stored in the PPCM area for use in a spoofing scenario.

A similar segregated portion of the Y-12 Western Exclusion Area could be established for the monitored disassembly of TLI canned subassemblies. Applying PPCM to a segregated and dedicated dismantlement zone for TLI would mean that every warhead or CSA going into the dedicated zone would be dismantled, and no warheads would come out of the dedicated zone at Pantex, or CSAs out of the dedicated zone at Y-12. No components would go into the dedicated zone at either Pantex or Y-12, and every component coming out of the dedicated zone would be from a dismantled TLI warhead or canned subassembly. By making radiation fingerprint measurements on the warheads, canned subassemblies, and components it may be possible to identify a particular type of component with a particular type of warhead. This coupled with careful record keeping would provide the confirmation that warheads are being dismantled.

It was estimated for the purpose of making cost estimates that this segregated portion of Zone 12 could include 1 linear accelerator radiography bay, up to 11 mechanical disassembly bays, and up to 4 dismantlement cells at Pantex. A segregated portion of Y-12 subject to PPCM would be less extensive. The preparation and initialization of the segregated dismantlement zones would be relatively costly. This monitoring activity would require permanent presence or very effective remote monitoring.

SWEEPING OF THE BAY OR CELL BEFORE AND AFTER DISMANTLEMENT

Sweeping of the bay and cell is defined as allowing the inspectors to search the bay or cell before dismantlement to determine that there are no nuclear warheads (or CSA if implemented at Y-12) or nuclear components present before dismantlement, and no undeclared portals by which nuclear components or nuclear warheads could enter or exit the bay or cell. The inspectors would then examine the declared warhead in the staging bay outside of the bay or cell and determine that it is an actual TLI warhead, or a specific TLI warhead, using fingerprint measurements and TIDs. The warhead is then taken into the bay or cell to be separated into components (pit, canned subassembly, HE, and non-nuclear components) in the absence of the inspectors. When nuclear components (pit and canned subassembly) in sealed containers are removed from the cell, the inspectors perform radiation measurements or fingerprint measurements in the staging bay outside of the cell, and apply TIDs to the containers. The inspectors then search the cell to determine that no nuclear components remain in the cell. Chain-of-custody could then be applied to verify that the components are placed in monitored storage.

Dismantlement in a swept bay or cell would allow the inspectors to verify that specific components came from a specific warhead, by ruling out other possibilities. This activity is the extension of the chain-of-custody into the dismantlement bay or cell itself, and would be extremely valuable if the monitoring of dismantlement of specific warheads was required. It could be classified or unclassified depending on the measurements permitted inside the bay or cell, and the degree of masking that is done before the inspectors enter the bay or cell.

DIRECT OBSERVATION OR REMOTE MONITORING OF THE DISMANTLEMENT PROCESS IN A BAY OR CELL

Actual observation of the dismantlement process, whether done remotely or directly, would produce the highest confidence that dismantlement is taking place. Routine use of this activity could be appropriate if a very high level of confidence in dismantlement is required as part of a true verification regime. Direct observation or remote observation of dismantlement could also be performed on a limited basis, for example, if the inspectors wanted to "guarantee" that a component came from a specific warhead so that a template for radiation signature measurement could be developed, or to resolve an "ambiguity" in the dismantlement process.

In order to perform this activity a dismantlement cell would have to be specially prepared to protect information that is not intended to be shared with the inspectors. The inspectors would then observe the dismantlement process either by going into the cell or through the use of remote monitoring techniques such as closed circuit television (CCTV). Because of the critical nature of the components and processes being observed, the prevention of inadvertent disclosure of sensitive information in this activity would be very difficult.

However, an opportunity for unclassified direct or remote observation of the dismantlement process may be presented by the Pantex SS-21 (Seamless Safety for the 21st Century) dismantlement process, which makes extensive use of specialized tooling and carefully prescribed operations to ensure safety in the dismantlement process. It might be possible to mask the most sensitive aspects of the dismantlement process by building sufficient visual shielding into the SS-21 tooling to allow the presence of inspectors in the dismantlement cell during dismantlement. With careful red-teaming and extensive security review of this approach, it could be possible to allow direct observation or remote monitoring of the dismantlement process in the bays and cells without revealing Restricted Data to the inspectors. The SS-21 process currently has no provisions for protecting the classified information that might be revealed during the dismantlement process. Although it seems simple to incorporate measures to protect classified information, only a thorough review of the needed measures, and their impact on the safety of the dismantlement process, will reveal the feasibility of incorporating those measures into the SS-21 process.

MONITORING OF NON-NUCLEAR COMPONENTS

While earlier studies concluded that monitored destruction of non-nuclear parts of dismantled warheads would, by itself, have little arms control significance, the study group which prepared this report concluded that the monitoring of non-nuclear components can add to the preponderance of evidence that functional nuclear warheads are being dismantled and that a proper disposition process is in place for all major nuclear warhead components. Verified destruction of non-nuclear major components may increase confidence that a particular type of warhead has been dismantled and that a country's capability to regenerate those warheads has been made more difficult. Monitoring of non-nuclear components includes the physical and administrative tracking of components as they are removed from the warheads and rendered inoperable or destroyed, and could include the use of video equipment or direct observation.

For this study non-nuclear components are defined as those components from nuclear warheads that do not have bulk quantities of fissile material. Therefore, non-nuclear components include warhead components that could be radioactive or contaminated by radioactive material due to proximity to nuclear components. Also included in this category are major nonnuclear components (MC) of the nuclear warhead that are required for it to function as a weapon system. The following categories of MC are considered non-nuclear for this study:

- HE in all forms that are part of a nuclear warhead, including detonators
- Radiation cases and channels
- Reentry vehicle aero-shells
- Nuclear initiators, neutron generators, and tritium storage containers
- AF&F sets, including all components associated with the HE initiation train; radar fuse, impact fuse, RTGs, batteries, etc.

Depending on the warhead type, other non-nuclear components may be identified as items which would be significant to monitor. Monitoring the disposition of non-nuclear components can be accomplished with a reasonable amount of workplace and procedural modifications. Since a significant number of the non-nuclear components are unclassified in U.S. systems, shrouding techniques and administrative procedures could prevent the loss of sensitive information. For example, for one of the warhead types currently undergoing dismantlement, the Pantex nuclear warhead dismantlement process has been broken into twenty major steps. Eighteen of these steps (90% of dismantlement operations) involve tasks and operations that fall into the non-nuclear category.

RADIATION SIGNATURES

The use of radiation signatures is applicable to several of the monitoring activities including spot checks, chain-of-custody, portal perimeter continuous monitoring, and sweeping of a bay or cell before and after dismantlement. Radiation signature techniques involve measurements of the radiation emitted from a warhead before dismantlement, and from the components following dismantlement. If these signals can be correlated, one can obtain increased confidence that dismantlement is taking place without having to intrude within the dismantlement area.

There are two distinct types of radiation signature measurements: intrinsic and induced.

In passive (intrinsic) measurements, one makes use of the spontaneous radiation emitted by the nuclear materials before and after dismantlement to produce the needed correlations. In active (induced) measurements, one interrogates the warhead, and perhaps the components, with an external radiation source, and attempts to correlate the resulting induced radiation patterns.

Templates

For many of the radiation signature schemes it may be necessary to employ a template-matching approach to analyze the data. Templates may be applied in two ways. In the first approach one originally accumulates, by some means, a series of authenticated radiation signatures or "templates" describing the various different warhead and component types. Then during inspections the signature obtained is compared to the library of templates that is available to the inspectors, and it is determined which warhead type or component type matches the radiation signature of the item being inspected.

In the second method one obtains the templates as the radiation signatures from the first unit to be dismantled and the components removed from it, and then compares the radiation signatures for all similar units to these templates to determine whether they are the same as the first unit of that declared type.

In many cases the information contained in the templates is classified, which restricts the utility of these methods. However, it may be possible to ***compare*** a radiation signature to a classified template without revealing classified information, by displaying to the inspectors only a "Yes" or "No" answer to the question "Does this radiation signature match the template?"

Radiation Signature Technologies

A detailed description of warhead radiation signature technologies is provided in Appendix E. Several examples of radiation signature techniques that may have utility for dismantlement monitoring are discussed below:

- **Gamma Ray Spectral Measurements:** The Sandia Remote Monitoring System (RMS) is currently in use at the Pantex facility for domestic safeguards purposes. This system measures the gamma ray spectrum from a pit, both in the warhead configuration and after dismantlement. The NaI spectrum is then binned into a low resolution spectrum which is used to distinguish various component types. This is a totally passive system, and can be carried out in a portable configuration. Both the high and low resolution spectra taken with systems like the RMS are classified.

- **Controlled Intrusiveness Verification Technology (CIVET):** CIVET consists of a set of hardware, software, and procedures designed for the purpose of permitting an inspecting party to perform a high-confidence inspection while at the same time providing assurance to the inspected party that sensitive data are not revealed to the inspector. In the CIVET high-resolution gamma-ray spectroscopy (HRGS) system, the hardware was especially designed to minimize the opportunity for clandestine data storage or transmission, and the software was developed to perform all data acquisition, spectrum data analysis, peak data computation, and template comparison functions with minimal operator input, and to display verification conclusions containing no sensitive or classified information.

- **Nuclear Weapons Identification System (NWIS):** NWIS has been under development for several years at Oak Ridge, and has been applied with success at the Y-12 facility. The system has proven particularly useful for CSAs, which are resistant to gamma ray spectral techniques because of the low intrinsic radiation signal from HEU. In the NWIS system one interrogates the item being inspected with a ^{252}Cf neutron source which is built into an ionization chamber. Thus one has an exact time for the birth of the neutrons used for the interrogation. The system then measures the correlations in arrival time between this counter and several neutron or gamma detectors placed around the object being inspected, or between any two of the detectors. In all, the system generates 19 correlations, some of which show very high sensitivity to small changes in the warhead configurations. Even though the actual template generated by NWIS for each warhead or component is classified, the results of NWIS can be displayed on the unclassified level by comparing only the differences from each template or by normalizing the results of each measurement. While this normalizing technique was used effectively during the Russian demonstration at Y-12 in November 1996, the question of the classification of NWIS signals will need to be further investigated to ensure that no warhead design information can be extracted from the signals.