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TECHNICAL CHALLENGES FOR DISMANTLEMENT VERIFICATION

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Abstract

In preparation for future nuclear arms reduction treaties, including any potential successor treaties to START I and II, we have been examining possible methods for bilateral *warhead* dismantlement verification. Warhead dismantlement verification raises significant challenges in the political, legal, and technical arenas. The following discussion will focus on the technical issues raised by warhead arms controls. Technical complications arise from several sources. These will be discussed under the headings of warhead authentication, chain-of-custody, dismantlement verification, non-nuclear component tracking, component monitoring, and irreversibility. We will discuss possible technical options to address these challenges as applied to a generic dismantlement and disposition process, in the process identifying limitations and vulnerabilities associated with various approaches and suggesting methods to reduce possible vulnerabilities. We expect that these considerations will play a large role in any future arms reduction effort and, therefore, should be addressed in a timely fashion.

Warhead Authentication

A particularly difficult problem is assuring that an object presented for dismantlement is actually a nuclear weapon. On purely technical grounds, it seems likely that an item can be determined to be a warhead using a combination of gamma-ray and neutron detection techniques. However, legal and policy issues will surely affect how precise such measurements can be, which impacts their effectiveness. For example, details on isotopics and mass of some components may be classified, and detailed gamma-ray and neutron measurements would reveal this information.

Several approaches under investigation may help to address these issues. Examples of potential solutions to this problem include combining neutron and gamma-ray signals into a single multiplicity circuit to get a "fingerprint" of a weapon and then measuring again to obtain a fingerprint of the resulting component. For this measurement, we believe that the inspectors can observe the measurement data because the complexity of the combined neutron and gamma ray multiplicity information does not allow the inspector to reverse engineer design details.[1] Alternatively, it may be possible to make high-fidelity measurements and then compare measurement results to expected results in software that generates an unclassified output statement such as, "the data are highly consistent with this item being a nuclear warhead."

Analyses of the efficacy of these measurements both in protecting design information and in authenticating warheads are still preliminary. Of course, each of these types of applications must be thoroughly analyzed before they can be viewed as solutions to the authentication problem.

The development of such technologies provides an opportunity for the policy and research communities to work together to facilitate timely development of applications. The development and maintenance of close ties between these communities can help improve the chances that the technical approach will address the overall policy needs and will keep the policy community abreast of the technical state of the art.

The mutual reciprocal inspection (MRI) effort between the United States and Russia to identify transparency approaches that might be used to provide confidence that the item within a container is a weapon component provides a model where the technical and policy communities have worked effectively together to find a technically sound approach to a significant policy need. MRI could provide a basis for supporting dismantlement transparency in general. However, even this mature effort would necessitate the exchange of some limited amount of classified weapon design information, which demonstrates the nontrivial nature of the challenge of balancing confidence in measurement information with complete protection of design information.

Chain-of-Custody

Chain-of-custody presents an interesting set of verification problems starting with shipment from the defense facility to the dismantlement plant and continuing through the removal of different layers of material during dismantlement. Tags and seals have been proposed as one means of establishing chain-of-custody. Within a transparency regime, conventional tags and seals might provide incremental confidence to shipment declarations. However, recent studies have shown that most tags and seals are highly vulnerable to tampering when they are not being monitored.

In one study, every seal tested was defeated within five minutes (if the seal was not under some form of monitoring). If properly examined in an autopsy, most of these failures could be detected once the seal was removed but some could not. This study demonstrated that without careful considerations as to selection of which tags or seals to use, the establishment of procedures for their application, removal, and autopsy, and monitoring of the seals between application and removal, tags and seals may be of limited value in maintaining the chain-of-custody of an item. Careful assessment of these questions will be required to improve the utility of tags and seals in warhead arms control.[2]

Dismantlement Verification

The most critical area is the actual dismantlement of the nuclear warhead. Chain-of-custody procedures, while problematic, can provide some assurance that warheads are brought into the dismantlement area and components are removed. However, the real challenge of such a regime is to ensure that the treaty limited warhead is actually dismantled without revealing more design information than desired. Studies now under way are addressing certain technologies that might be applied. These include use of methods of sweeping a room to ensure no "dummy" warheads or components are present, remote monitoring, means of masking an inspector's view to exclude access to sensitive information, portal perimeter monitoring, and the use of radiation-based techniques to demonstrate a correlation between a weapon brought in and components brought out.

Nonnuclear Component Tracking

The tracking of nonnuclear components is commonly cited as a means to add to the preponderance of evidence of dismantlement. While on the surface this sounds plausible, in a resource-limited world it might actually detract from the overall effectiveness of dismantlement transparency/verification because those people engaged in tracking and verifying nonnuclear components will not spend time on the main item(s) of interest—the nuclear components. Generally, nonnuclear components are comparatively inexpensive, their passage in or out of a portal cannot be detected unless extremely intrusive procedures are employed (such as a visual search of each and every container), and any nation engaged in dismantlement may have a large stockpile of existing discarded components from previous dismantlement activities that are outside the scope of a particular agreement. Demonstrating that nonnuclear components come from authentic, recent dismantlement activities could be a daunting task.

Moreover, many nonnuclear components may contain information relevant to the design of the weapon.

In anticipation that, at some level, tracking of nonnuclear components could become part of a transparency regime, we have been examining technical options for establishing that a nonnuclear component actually comes from a recently dismantled warhead. In select cases there may be solutions to this problem, but the analyses are in their early stages, and measurements would be time consuming—again limiting the utility of nonnuclear component tracking in warhead dismantlement verification.

Component Monitoring

The basic goal in monitoring nuclear components resulting from dismantlement is to correlate the component with its warhead of origin to gain confidence that dismantlement is indeed taking place.

Correlation of components with their warheads of origin might be attempted through declarations, albeit at a very low level of confidence. In some relevant cases, it *might* be possible to perform intrinsic radiation measurements that uniquely identify that a type of component came from its associated type of weapon, but any equivalent of a unique intrinsic radiation "serial number" on the component is unlikely to exist.

Technical challenges are associated with even measurements that correlate a component type to its associated weapon type (rather than an individual warhead). These include the possibility that there may be classified information about materials between the outer case and the component itself. Thus, one must be careful in comparing the measurements before and after dismantlement that the inspecting party cannot infer more information than the inspected party wants to divulge.

Irreversibility

Irreversibility is the process of assuring that the warhead reductions obtained by dismantlement are not lost through production of additional weapons. Irreversibility has two components: First, to assure that material removed in the dismantlement process is not being returned to new fabrication; second, to assure that there is no hidden stockpile of fissile material that could provide undetected feed for new weapons production. Both of these concerns are related to "initialization," which is the initial declaration of fissile material and nuclear weapon pertinent information. At a minimum, initialization necessarily includes declarations of fissile material inventories, production, location, and characteristics-related information. Depending on the degree of confidence desired (low-to-high) in an agreement, the detail and type of information declared in initialization will vary and possibly include nuclear weapon stockpile inventory and location information.

Of course warheads must be maintained in order to remain reliable. In some cases this maintenance involves return of warhead systems to assembly/disassembly plants. Distinguishing legitimate maintenance from illegitimate new production at these facilities may necessitate highly intrusive measures at the production facilities. An example of such a measure would be continuous perimeter portal monitoring around the entire facility. However, because of the size of the potential treaty-limited items, it may be necessary to perform internal radiation scans on every vehicle, and radiation surveys on every package larger than a bread box that enters or leaves the facility (a very large and costly task at any industrial-scale facility).

Technology development that can reduce the burden of human presence for inspections or continuous monitoring could increase both the attractiveness and efficacy of this perimeter portal monitoring.

An alternative approach to the irreversibility problem would be to establish high confidence in the baseline of each side's weapons and fissile-material stockpiles. Conventional safeguards can certainly add to the degree of confidence in irreversibility. However, because of the large material quantities involved and the uncertainties in material quantities, safeguards would have to be supplemented with other transparency measures to improve confidence in the lack of possible hidden stockpiles.

The challenges for technology here are twofold. The first is to continue to improve and implement technology that will decrease measurement uncertainties of identified materials. The second challenge is to develop and field technology that would minimize intrusiveness of challenge-type inspections so that a host country could cooperatively demonstrate the absence of significant nuclear activities in locations where an inspecting country suspects inconsistencies with declarations.

Conclusions

The possible advent of warhead arms control has opened up a broad spectrum of technical challenges to those who are currently developing verification technologies. The Department of Energy has taken the lead in developing such technologies, but it is currently too early to determine the exact shape warhead arms control may assume and therefore where the most urgent policy needs lie.

The technical challenge then becomes making a measurement that is rigorous enough to conclude that the item is a weapon, while maintaining security over the information that is considered classified. This is exacerbated by the fact that the United States and Russia have different classification guidelines, which further reduces the subset of information that could be exchanged.

References

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2. Roger G. Johnston, Anthony R. E. Garcia, and W. Kevin Grace, "Vulnerability Assessment of Passive Tamper-Indicating Seals," *Nucl. Mater. Manage.* **XXIII**(4), 20-23 (July 1995).