Verification and transparency-related issues, focused on nuclear warhead and delivery vehicle reductions and the CTBT

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Abstract

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ABSTRACT

The perceived stability of a world with nuclear weapons and particularly with a rapidly decreasing number of nuclear weapons can be enhanced by appropriate practices and policies in regard to transparency, supported by measures to verify arms limitation agreements that may be in force at the time. In the long interim before nuclear weapons can be eliminated, and whether they can or cannot be eliminated, we need to understand activities of Nuclear Weapon States compatible with a reduced dependence on nuclear weapons, and with measures to prevent the spread of nuclear weapons to additional states and non-state groups. States not party to the NPT which possess nuclear weapons may be able to adopt some of these approaches, with benefit to regional stability.

The work conducted by Nuclear Weapon States to maintain nuclear weapons safe, secure, and reliable must not be confused with expanding the scope or utility of nuclear weaponry, and even before the CTBT enters into force, sub-critical experiments that use fissile material should be demonstrably compatible with the CTBT ban on any nuclear explosion test with yield above zero.

Control and accounting and eventually verification of nuclear weapon numbers and locations can be aided by a system sketched in a 2005 report[1] of the U.S. National Academies' Committee on International Security and Arms Control (CISAC) that would permit a state to keep track of its nuclear weapons in real time and opens the way for optional transparency and exchange of information with selected states. A continuing exchange of encrypted data (more precisely, of "hashed" data) would provide no information beyond that involved in some later agreed validation of the database by the sampling of a few individual weapons.

In similar fashion, dismantlement of nuclear weapons can be verifiable and demonstrable, with the preference that nuclear bombs and warheads be accountable and counted as to the number that exist and not simply the number that have been dismantled or destroyed.

The New START agreement between Russia and the United States lays the groundwork for some of these tools; of interest is not only the implementation but also the extent to which these measures can be adopted by other states.

INTRODUCTION

This is a technical talk and not a political talk, and I am primarily a technical person who has worked for many years in creating nuclear weaponry and in attempting to ensure that U.S. and foreign weapons are as safe and secure as possible. I have, in addition, tried to use scientific and technical understanding to guide arms control agreements that would serve the security interests not only of the United States and its friends and allies, but, evidently, all signatories of these agreements. At times, there was considerable tension and even antagonism among some of the signatories.

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[1] Monitoring Nuclear Weapons and Nuclear-Explosive Materials: An Assessment of Methods and Capabilities, National Academies Press, 2005, (http://www.nap.edu/catalog.php?record_id=11265)

Technically, the world finds itself today in a condition that should be much safer than in the past, as regards a massive exchange of nuclear weaponry. But although nuclear weapon stocks in the United States and Russia have been much reduced from the levels of the 1960s and 1980s, beyond the deployed and operational weapons there are many more. Although these are not, for the most part ready for immediate use, they could be reconstituted, in general, more rapidly than similar numbers could be built from scratch.

CURRENT NUCLEAR THREATS AND NUCLEAR FORCES

The 2010 Nuclear Posture Review ("2010 NPR") was published April 6, 2010 as an unclassified 49-page document[2]. It was a product of intense cooperation among various agencies and departments of the U.S. government and is intended to guide U.S. nuclear-weapon related and security postures for the next five years, at least. In conjunction with the 2010 NPR, the United States released details about its nuclear stockpile, including the fact that it had "5,113 warheads" in its nuclear weapon stockpile as of September 30, 2009.

U.S. nuclear warheads had reached an official high of 31,255 in 1967, driven, in my own judgment, by a combination of capability to produce large numbers, on the one hand, and a justification that such large numbers were required to deter massive attack on U.S. weapons themselves, and to counter potential defensive capabilities that could prevent bombs and missile warheads from reaching their intended targets if the warheads survived destruction before launch.

Neither Russia nor the United States faces such a threat now, and, whatever the utility of nuclear deterrence, the number of U.S. and Russian weapons poses not only a burden of cost, but also adds to the vulnerability of these and other societies, and impedes political efforts to limit the acquisition of nuclear weapons by others. That vulnerability is particularly acute as regards terrorist acquisition and use of nuclear weapons or weapon-usable highly enriched uranium (HEU) or plutonium.

Even at the time of massive stockpiles of the United States and the Soviet Union, and hence overwhelming capability to destroy one another, nuclear deterrence was extended to states not possessing nuclear weapons, via NATO and the Warsaw Pact, and through bilateral agreements and understandings such as the United States has had with Japan and South Korea, and with other partners in the world.

Developments and investments were made to limit potential destruction by nuclear weaponry, including the deployment of massive air defenses against bomber-delivered weapons, and the development and deployment of defenses against long-range ballistic missiles—notably a nuclear-armed defense of the Moscow area in the Soviet Union (and now Russia) and a short-lived U.S. defense of its retaliatory ICBM force (the Safeguard System). Damage limitation was also sought by the design and deployment of weapons of accuracy sufficient to threaten missiles that had not left their silos.

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[2] http://www.defense.gov/npr/docs/2010%20Nuclear%20Posture%20Review%20Report.pdf

By the late 1960s, though, particularly in the United States, leaders recognized that the technology of the day was such that defenses could not protect population centers, and that it was desirable if nuclear weapons persisted, to increase the stability and hence reduce the likelihood that they would be used, and also to limit their numbers.

Initially reluctant, the Soviet Union agreed to constrain its defenses and to impose some limits on the buildup of offensive strategic nuclear forces. This recognition culminated in the ABM Treaty of May 26, 1972 and the accompanying Limited Offensive Agreement. These bilateral agreements, to the extent that they improved stability between the United States and Soviet Union, contributed greatly to stability and survival of the entire world, because a massive exchange of nuclear weaponry would have killed billions—most of them not targeted—by environmental effects, the collapse of the world trading system and the world economy, and by physical effects such as the destruction of the ozone layer and the failure of crops because of the pall of smoke and dust lofted to the stratosphere from the combustion following nuclear detonations over cities and forests.

Nuclear weapons are not a solution to most of the security problems of modern societies. They have little to contribute in countering terrorism—even in countering terrorist use of a nuclear weapon. In my writings, I join the majority in stating that terrorists are most likely to use improvised nuclear weapons, and of these improvised nuclear weapons, gun-assembled weapons of HEU either contained in a van and detonated in the street of a major city, or covertly assembled in an apartment or basement in a building in city. Nevertheless, preventing terrorist acquisition and use of some national nuclear weapon—even from the U.S. and Russian armories that constitute more than 95% of the world's stocks—drives the augmentation of security controls over the theft or transfer of the weapons, and even of their detonation. It is also a major driver of reduction of numbers of weapons and particularly of consolidation and protection of weapon-usable HEU or plutonium.

CAN THE DESTRUCTION OF NUCLEAR WARHEADS BE VERIFIED?

Nuclear disarmament was furthered by the treaty between the United States and the Soviet Union eliminating nuclear forces of intermediate range ("INF") specifically all land-based cruise missiles or ballistic missiles of 500-5500 km range worldwide, whether armed with nuclear or non-nuclear warheads. The verification measures introduced to ensure that these missiles were destroyed and that replacements were not manufactured were extensive and relatively costly. They were carried out successfully.

The nuclear warheads from these missiles were, however, not required to be destroyed, and testimony to the United States Senate implied that such warhead destruction could not be monitored with confidence. I disagreed with that view, and judged that warhead disassembly and destruction can be verified adequately, with a proper agreement and facility, and that this should be done in the future, although such verification of destruction should not preclude agreements to verify numbers of nuclear weapon and nuclear weapon carriers in the forces. My view is that there was no will to destroy the cruise-missile warheads, which might be repurposed for other delivery means.

In brief, in support of potential agreements to limit nuclear warheads, nuclear weapons in the actual forces should be identified and fitted with an identifying tag and a "seal" that would follow them and ease their verification and counting, even though there was no treaty in force to limit their numbers. Of course, without an agreement there is no requirement to report these numbers to the potential partner(s) in a future agreement, but such tags and seals can greatly assist a nation to manage and control its own nuclear weapons.

In support of an agreement to destroy some nuclear weapons, such a sealed nuclear weapon would be delivered to the dismantlement site of the country owning that nuclear weapon. It would be checked into the site and into a specific room, which would otherwise be free of fissile materials. After the dismantlement, three streams of materials would emerge—high explosive and perhaps other hazardous waste, non-nuclear elements such as metals and plastics, and fissile materials (plutonium and uranium). It is these last that would be monitored, and in any case, it would be verified that no fissile material was left in the disassembly room, and that it could not have been spirited away. It is also necessary to establish that the claimed nuclear warhead is indeed a warhead or bomb of the claimed class, and the best way to determine that is to select the warhead at random from the deployed forces, maintaining joint custody of the warhead (aided by its tag and seal) from its dismounting from the missile carrier until it enters the portal of the dismantling facility.

In this regard, there has been a lot of analysis and experimentation on the mechanism of monitored/verified dismantlement, including a SIPRI book of 2003, in which I have a relevant chapter)[3] and, especially, a UK-Norway exercise organized and reported by VERTIC.[4]

From this latter report of September, 2010, we take the concluding sentences:

> *"It is therefore, possible to state that, despite a number of unsatisfactorily resolved hurdles, there is nothing to suggest that the verification of warhead dismantlement is not technically feasible. And nothing, moreover, to suggest that dismantlement verification cannot be kept within acceptable levels of tolerance—both in terms of intrusiveness and reliability."*

No one said that it would be easy, and much more work remains to be done. Fundamentally, what is required is assurance that the object that enters the dismantlement facility is indeed a nuclear weapon of the proclaimed type, and that the fissile materials are verified to leave the facility in a stream that is henceforth irrevocably committed to civil purposes.

VERIFYING NUMBERS OF EXISTING NUCLEAR WEAPONS CARRIERS, WARHEADS AND BOMBS

Of course, I don't need to explain to this gathering that the CTBT, in itself, does not ban nuclear weapons. In banning "*any nuclear weapon test explosion or any other nuclear explosion*" it is setting a restriction that is fundamentally unverifiable by the International Monitoring System. Nevertheless, as stated by the late Paul Nitze in several contexts, the CTBT is "effectively verifiable," in that the violations that could not be detected

[3] "Technologies and procedures for verifying warhead status and dismantlement," by R.L. Garwin, chapter in "Transparency in Nuclear Warheads and Materials: The Political and Technical Dimensions," Edited by N. Zarimpas, SIPRI, Oxford University Press, 2003, pp. 151-164. Presented at SIPRI Workshop, Paris, 02/08-09/2001.

[4] http://news.bbc.co.uk/2/hi/8154029.stm re Vertic UK/Norway dismantling exercise.
http://www.vertic.org/assets/Events/090509%20UK-Norway%20Initiative%20Presentation.pdf
(prospective)
http://www.vertic.org/assets/Publications/VM9.pdf
(September 2010)

with confidence do not have military consequence. This has been discussed in detail in the 2002 NAS CTBT report, and is the subject of a further report revisiting these questions in the 2010 context.

Some experts in nuclear weapon states argue that only dismantlement and destruction can be verified, and that it is not practical to verify the numbers of nuclear warheads in existence—but ONLY those that have been subject to dismantlement.

Just this question was addressed by The National Academies' Committee on International Security and Arms Control (CISAC) in its 2005 volume, "Monitoring Nuclear Weapons and Nuclear-Explosive Materials." To monitor nuclear warheads is, in principle, a much simpler job than to verify bulk stocks of fissile material. Both tasks, however, are eased by the fact that for the most part these are "discrete" items. Warheads are evidently discrete, and separate one from the other. Because of the problems of criticality, stores of fissile material are typically in small containers to prevent corrosion and to prevent accidental "criticality" that could occur if too much fissile material is assembled in proximity. The approach can be illustrated in the case of warheads, which should be equipped with a tag and seal. The New START agreement of April 2010 between the United States and Russia requires a unique identifier[5] ("UID") to be assigned to each ICBM, SLBM and heavy bomber to facilitate monitoring throughout the life of the Treaty; such techniques could readily be extended to nuclear bombs and warheads.

Although the New START limits warheads and bombs on the two sides to a total of 1550, that total can be substantially exceeded, since each heavy bomber is counted as a single (one) warhead, despite the fact that a heavy bomber could carry 20 or more cruise missiles, together with at least that many ordinary nuclear bombs.

Briefly, to lay the groundwork for some future limit and accounting and verification, without providing any information at present, a state considering an agreement could identify for its own purpose each potentially Treaty Limited Item (TLI), and enter its characteristic into a database as a single line that would include identifying information, serial number, tag number, and location. As that weapon was moved from storage to maintenance and from maintenance to deployment, the line in the table would be changed in order to remain current. Such a database would no doubt be highly classified because states would not ordinarily want other states to have these details of location or even of numbers of all of their nuclear-capable forces. Nevertheless, at some later time, a state might see it in its security benefit to limit its numbers in return for limitations on the numbers of other states.

Even with such agreements, precise locations and movements might not be treaty accountable and should be concealed, but the integrity of a database could be verified by sampling. This could be done by asking side A to reveal the location and identity of a particular warhead, perhaps selected at random from lines in the database. But how would vital information be kept from side B, other than the few samples and little sampled information that it is desired to exchange?

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[5] The term "unique identifier" or "UID" means a non-repeating alpha-numeric number that has been applied by the inspected Party to an ICBM, SLBM, or heavy bomber.

As indicated in the 2005 Report[6] it is possible to verify that the data have in fact been in the hands of side B when they are revealed on a sampled basis, without side B being able to deduce any data at all from the information in its possession. This would be done by exchanging a "hashed" version of each line, which might take 2048 bits (256 characters) of structured text representing the identity and location of the TLI, and reducing it to 160 or, for that matter, 256 bits, each of which is a complicated function of the data itself. There is a large literature and analytical basis for the security of such hashed data. Briefly, no matter the ingenuity of side B, the information is just not there to deduce the original data from the hashed version. The hashing process is totally open[7] so that when side A wishes to present side B with the data to allow side B to verify the location and identity of that particular TLI, side B could immediately, and with high confidence, hash that claimed data line itself to verify that it obtains the hashed line that has long been in its possession.

The requirement in New START for each of the weapon carriers (the TLI) to have a Unique Identifier might jump start the evolution of such a scheme that would be capable of monitoring the warheads themselves.

VERIFYING COMPLIANCE WITH THE CTBT, WHEN IT ENTERS INTO FORCE

To verify compliance with the Comprehensive Test Ban Treaty of 1996, that bans nuclear explosion tests or any other nuclear explosion anywhere, in any medium the CTBT organization and its supporting States have constructed the International Monitoring System (IMS) that is now almost complete. As indicated in reports from the CTBTO and, for instance, a 2002 report from CISAC[8], the goal of the IMS is to detect, locate, and identify as an explosion a nuclear explosion of yield exceeding one kiloton. In fact, the capability of the IMS, supplemented by detection systems that do not belong to the IMS, is much better than 1 kt in many places of interest, such as the traditional nuclear explosion test sites of Russia, China, and the United States. This is due in part to the many thousands of seismometers operated by governments and universities primarily for detecting and warning of earthquakes and the like. These digital seismometers can have their data processed after the fact to form "arrays" and "smart arrays" that do a much better job of detecting signal in the background noise and confusion of other earthquakes, for instance. The results are very impressive.

But the CTBT bans nuclear explosions not just above 1 kt but above even one microgram of high-explosive-equivalent release of nuclear energy. An appreciation of the quantities involved can be obtained from the fact that the total fission of 1 kg of plutonium or uranium would yield about 17,000 tons of TNT equivalent. Thus one ton of yield corresponds to about 60 milligrams of fissile material fissioned, and one gram of yield corresponds to 60 nanograms of fission.

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[6] "Monitoring…", Pp. 56-60. A data "line" of thousands of characters would be handled in identical fashion.

[7] "Monitoring…", Pp. 92-96; refers to Secure Hash Algorithm SHA-1 (160-bit message digest), and SHA-256.

[8] "Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty," by J.P. Holdren (Chair), H. Agnew, R.L. Garwin, R. Jeanloz, S.M. Keeny, Jr., C. Larson, A. Narath, W.K.H. Panofsky, P.G. Richards, S. Sack, and A.W. Trivelpiece, Committee on Technical Issues Related to the Ratification of the Comprehensive Nuclear Test Ban Treaty, National Academy of Sciences (National Academies Press, July 31, 2002. Available for reading or download at http://www.nap.edu/html/ctbt/)

Still, even one gram of TNT-equivalent fission is readily measured in an experiment, as emphasized by an open report[9] of the JASON group of consultants to the U.S. government, and in this case to the National Nuclear Security Administration.

The conduct of an experiment that yields a sudden, explosively-driven chain reaction of 1 g of TNT equivalent could certainly be concealed from the IMS. There have been many analyses as to whether the release of such energy or the information obtained from such an experiment could lead to technically significant advances, and the 2002 Report concludes that it could not. Of course, much knowledge of nuclear weapons could be obtained without experiment or through experiment that has no yield at all and might consist of fixed assemblies of fissile material to study the approach to criticality, for instance. One of the tests analyzed in JSR-97-300 used 81 pounds (36.7 kg) of high explosive to drive 462 grams of Pu, but the configuration was incapable of driving the Pu to criticality.

The referenced Report shows that if a CTBT participant wished to provide assurance regarding a test it claims was sub-critical, even though driven by high explosives, it could readily provide such assurances to another state or international organization by the use of ordinary neutron or gamma-ray detectors in or near the experimental room in which the experiment is carried out. This could be done without providing any detail except that there was no release of fission energy nearby exceeding a tiny fraction of those discussed just now.

THE ROLE OF SCIENCE AND TECHNOLOGY IN DISARMAMENT

Science and technology (S&T) underlie the inspection and verification capabilities, but it is easy to miss the S&T incorporated in the fantastic tools of modern society such as satellite systems for positioning (GPS) and observation—both commercial systems for optical and radar imaging, and national technical means. In a 2004 presentation[10] I have described such systems and also the role of data analysis. I provide there references to authoritative articles by Mark F. Moynihan and Albert D Wheelon on the evolution of those systems, and draw on an analysis by Bruce Blair of the refinement of judgment of a violation on the basis of repeated observations. I emphasize the need for advanced modeling and simulation of the command and control system for nuclear forces, not only in Russia and the United States but in other states possessing nuclear weapons. These simulations should include characterization of the individuals who are involved in these systems and should be extended with great benefit to other large and important programs of societies[11]

WILL EXTENDED DETERRENCE BE PROVIDED AS NUCLEAR WEAPONS ARE MUCH REDUCED IN NUMBER?

It is not to be expected that states possessing nuclear weapons will cease all work on nuclear weapons, even after a CTBT enters into force. The United States, for example, will continue its Life-Extension Programs (LEP) of existing nuclear weapons, as discussed in the 2010 NPR. This may

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[9] Subcritical Experiments, JSR-97-300, March 1997, (http://www.fas.org/programs/ssp/nukes/testing/jsr-97-300subexpmts.html)
[10] Science and National Intelligence, Presented August 20, 2004 at the 32nd session of the Erice International Seminars on Nuclear War and Planetary Emergencies. (http://www.fas.org/rlg/040820-sani.pdf)
[11] R&D Opportunities And Needs For The Economic Transition, William D. Carey Lecture AAAS Science and Technology Policy Forum April 30, 2009 (http://www.fas.org/rlg/042209%20R&D_Opportunites_and_Needs2.pdf)

extend to replacement of non-nuclear parts of the nuclear weapon, refurbishment of parts including the primary and secondary components of the nuclear weapon itself, upgrades to safety and security aspects of the nuclear weapon, and even, with the specific approval of the President, replacement of the primary or the secondary. The purpose, in the example of the United States is not to acquire new military characteristics but to maintain reliable, safe, and increasingly secure nuclear weapons to provide deterrence of nuclear attack. According to the NPR, *"The fundamental role of U.S. nuclear weapons, which will continue as long as nuclear weapons exist, is to deter nuclear attack on the United States, our allies, and partners."* But it is not precluded, in the NPR and in Presidential statements that nuclear weapons might be used in response to an attack by biological weapons, for instance.

According to the NPR, the United States remains fully committed to extending its deterrent capability to the support of its alliances. Even with reductions to a total stockpile, eventually including replacement weapons and weapon-usable material, of 1000 or 300 equivalent nuclear weapons, that guarantee would remain undiminished "as long as nuclear weapons exist."

CLOSING COMMENTS

The United Kingdom has proclaimed its nuclear weapon facility at Aldermaston "a disarmament laboratory," as stated by Foreign Secretary Margaret Beckett in 2007 and endorsed by Defence Secretary Des Browne in his speech to the Conference on Nuclear Disarmament, February 5, 2008. And as I have indicated, the U.K. and Norway have participated in a substantial exercise simulating dismantlement of a nuclear warhead, with Norway playing the role of a nuclear-weapon state.

Evidently, there is room for other states that are members of the NPT as non-nuclear weapon states to engage in the development and analysis of tools for conducting and verifying nuclear disarmament. It would be helpful also for the nuclear weapon states to invite routine IAEA inspection of their civil nuclear enterprises, for which additional support to the IAEA would be necessary. The cost of such inspections could be reduced if the facilities inspected had to pay that cost, an approach that could lead to the choice of facility design and operation that would minimize that cost.

Whether or not complete nuclear disarmament is achievable and desirable, major reductions in the stocks of nuclear weapons are in process and should be encouraged in the interest of security of all the world at risk of destruction by terrorist use of nuclear explosives. Science and Technology have a big role to play in both limiting and defending against this threat.

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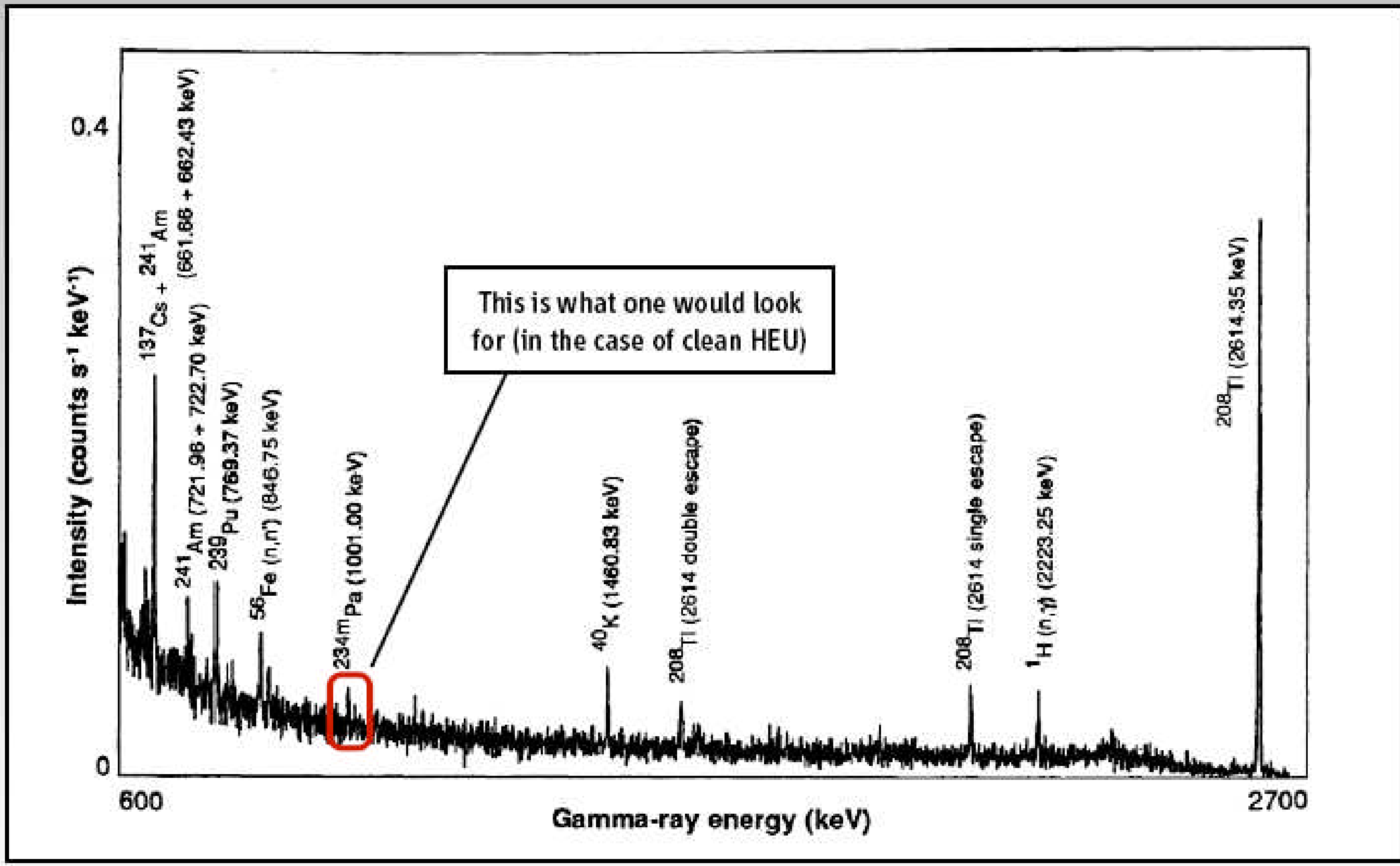
Supplemental material:

An alternative to a stable/unstable ZERO national nuclear weapons is a UN nuclear force. Horrifies most people; needs much imaginative, constructive analysis before rejection.

Stable national forces in a bilateral confrontation can be achieved if each side demonstrably has no capability to defeat ALL of the nuclear weapons on the other side.

Yes, some states will be motivated to build nuclear weapons so long as the 5 NPT “nuclear –weapon states” have them. But OTHER states will be motivated to build nuclear weapons if they are not covered by U.S. reassurance of extended deterrence. The NPR attempts to address both these concerns.



S. Fetter, T. B. Cochran, L. Grodzins, H. L. Lynch, and M. S. Zucker, "Measurements of Gamma Rays from a Soviet Cruise Missile," *Science*, 248, 18 May 1990, pp. 828-834

From Bruce Blair, as quoted in my Footnote 10: