DISCUSSION PAPER: MANAGING STOCKS OF SEPARATED PLUTONIUM TO MITIGATE SECURITY RISKS: NEAR-TERM STEPS

John Carlson

May 2015

John Carlson is a counselor to NTI, advising on international nuclear security, safeguards and verification, and management of the nuclear fuel cycle. He supports NTI's efforts in the Asia-Pacific region on nuclear security and arms reduction. He is a Nonresident Fellow at the Lowy Institute, a member of the Advisory Council of the International Luxembourg Forum, an Associate of the Project on Managing the Atom, Belfer Center, Harvard University, and a member of VERTIC's International Verification Consultants Network. Carlson was an official in the Australian government for more than four decades and served as director general of the Australian Safeguards and Nonproliferation Office.

Objective

To propose steps and commitments that states could consider in the near term for mitigating security risks with respect to separated plutonium.

Introduction

Separated plutonium presents particular risks in terms of both proliferation and nuclear security. Accordingly, separated plutonium is recognized as a sensitive material requiring special precautions during separation, storage, and use. However, mitigating risks associated with separated plutonium has not received attention comparable to the international actions taken for highly enriched uranium (HEU). Separated plutonium was referred to in the 2014 Nuclear Security Summit communiqué, albeit briefly. The communiqué said:

> We encourage States to minimize their stocks of HEU and to keep their stockpile of separated plutonium to the minimum level, both as consistent with national requirements (emphasis added).

This paper was commissioned by NTI to inform discussions related to the Global Dialogue on Nuclear Security Priorities. The views expressed are solely those of the author and do not necessarily reflect those of participants in the Global Dialogue, NTI officers or staff, or the NTI Board of Directors or institutions with which they are associated.

Thus, Summit participants have expressed support for keeping stocks of separated plutonium to a yet-to-be-defined minimum level. Minimizing stocks is an important way of mitigating both proliferation and security risks. Mitigation of risk also involves consideration of risks from the ways in which plutonium is handled—i.e., produced, stored, processed, transported, and used—and the elimination of non-essential holdings of separated plutonium.

Regarding minimizing stocks, the 2014 Summit communiqué is expressed in very broad terms, raising questions such as, what should minimization mean in practice, what set of principles could be developed and applied, and how should states collaborate to encourage implementation of agreed principles?

This paper considers steps and actions that might be considered with respect to separated plutonium, including as a follow-on to the reference in the 2014 Summit communiqué. While plutonium poses both proliferation risks and security risks, this paper focuses on proposals to address the security risks (i.e., risks of theft of separated plutonium that could be used by a terrorist to build a nuclear bomb).

What Is Meant by Separated Plutonium?

Separated plutonium generally refers to *unirradiated plutonium*, i.e., plutonium which has been separated from fission products and other elements through reprocessing of irradiated fuel or targets, until such time that the plutonium is loaded in a reactor and irradiated. This meaning is reflected in the Convention on the Physical Protection of Nuclear Material (CPPNM) which, in its Table on the Categorization of Nuclear Material, distinguishes between unirradiated plutonium and plutonium contained in irradiated fuel.[1] This distinction is also reflected in the *Guidelines for the Management of Plutonium* (INFCIRC/549), discussed below, which refers to "proliferation risks during any period of storage before the plutonium is either irradiated as fuel in a reactor or permanently disposed of."

The principal fissile isotope of plutonium is Pu-239. Plutonium used in nuclear weapons, commonly referred to as weapon-grade, has a Pu-239 content of more than 90%.[2] Currently plutonium separated from civilian spent fuel typically has a Pu-239 content ranging between 50 and 65% Pu-239. Although such plutonium is not weapon-grade it is considered to be weapons-

1. *Unirradiated* is defined as "Material not irradiated in a reactor or material irradiated in a reactor but with a radiation level equal to or less than 100 rads/hour at one metre unshielded."
2. There is no internationally agreed definition of *weapon-grade plutonium*, but in the Plutonium Management Disposition Agreement (PMDA) the United States and Russia have applied a definition referring to plutonium with a Pu-240/Pu-239 ratio of less than 0.10.

usable, and could be used by terrorists to produce a crude explosive device. Some plutonium in the civilian cycle has a Pu-239 content closer to weapon-grade,[3] and fast breeder reactors can produce weapon-grade plutonium in the breeding blanket. Also plutonium used in laboratories may be weapon-grade. This paper considers all forms of separated plutonium, whether weapon-grade or weapons-usable. It does not consider Pu-238, however, as that isotope of plutonium exists in separated form only in very small quantities, outside the nuclear fuel cycle, and is not a practical material for use as a nuclear explosive.[4]

As noted below, unirradiated plutonium can exist in various different isotopic, chemical, and physical forms, with corresponding degrees of attractiveness for potential terrorist use.

What Is Meant by Minimization?

INFCIRC/549 refers to the importance of balancing supply and demand, allowing for reasonable working stocks. This indicates the goal of supply (the rate of plutonium separation) not exceeding demand (the rate of loading plutonium-based fuel in reactors) in order to avoid building up a plutonium surplus. Put another way, the Guidelines suggest that plutonium should not be separated if it is intended for stockpiling rather than near-term use, as this is clearly inconsistent with the principle of minimizing stocks.

For practical reasons there is a requirement for working stocks—some plutonium needs to be on hand to allow for the time required to fabricate fuel and for fuel to be stored until it can be loaded in reactors. The question is what scale of working stocks can be considered "reasonable"? This would have to take account of overall fuel requirements in the state concerned, fabrication flow rates, schedule of reactor loading, facility-specific considerations, and so on. Also, there may be a case for having spare fuel assemblies on hand in case of the need to replace defective assemblies.

Guidelines for the Management of Plutonium (INFCIRC/549)

INFCIRC/549, published by the IAEA in 1998, sets out the only internationally agreed statement of management principles for plutonium in peaceful nuclear activities. The guidelines are intended to increase transparency of the management of civilian plutonium through each participating state (i) declaring that its policies for the management of plutonium are based on

3. For example, fuel from initial core loads.
4. The CPPNM does not apply to plutonium comprising 80% or more Pu-238.

these guidelines, and (ii) publishing annual statements of its holdings of separated plutonium.[5] Currently nine states subscribe to these guidelines.[6] Other states are invited to join.

Under the heading of *Policies for the Management of Plutonium*, INFCIRC/549 refers, *inter alia*, to:

> … the need to avoid contributing to the risks of nuclear proliferation, especially during any period of storage before the plutonium is either irradiated as fuel in a reactor or permanently disposed of; … [and] … the importance of balancing supply and demand, including demand for reasonable working stocks for nuclear operations, as soon as practical.[7]

INFCIRC/549 also contains important guidelines on international transfers (including consideration of the recipient's plutonium management strategy and timetable for utilization) and levels of security.

Near-Term Proposals for Plutonium Management

Minimizing Stocks

As already noted, minimizing stocks of separated plutonium would involve actions to bring supply (separation of plutonium) into line with demand (consumption as reactor fuel, or final disposition). Ensuring a balance in plutonium supply and demand will be an ongoing effort, i.e., extending over the medium and longer terms. In the near term, action is required to arrest the continuing growth in stocks.

Complicating factors in balancing plutonium supply and demand include: (i) major reprocessing states storing plutonium on behalf of customer states as well as themselves (so inevitably they have some stocks surplus to their own requirements); (ii) growth in stocks may reflect not only ongoing plutonium separation but also transfers of excess plutonium from military stocks; (iii) fuel fabricators require working stocks; and (iv) unintended delays in consumption due to program postponements or cancellations at reprocessing and MOX fuel fabrication facilities. Therefore, achieving a balance between supply and demand is not straightforward.

5. The INFCIRC/549 reporting *pro forma* does not indicate the isotopic composition of plutonium holdings.
6. The nine states currently participating in the INFCIRC/549 arrangements are the five NPT nuclear-weapon states plus Belgium, Germany, Japan, and Switzerland.
7. INFCIRC/549, paragraph 13.

Current status: As shown in the Appendix, overall quantities of separated plutonium in civilian programs are growing steadily–by some 39 tonnes (almost 14%) over the 10 year period 2003-13. The figures show considerable variation amongst different states. Putting aside the major reprocessors and the U.S. ex-military material, significant changes over the period include: the major reduction in German holdings; and the substantial increase in holdings in Japan.

By storing separated plutonium for customer states, the commercial reprocessors are helping to avoid an increase both in the size of plutonium holdings in these states and in the number of states with such holdings.

Challenges: A major challenge with respect to arresting the growth of stocks of separated plutonium, and balancing supply and demand is the absence of any international agreement on limitation of separated plutonium stocks. While the management policies set out in INFCIRC/549 are a good start, not every relevant state participates in the INFCIRC/549 arrangements (a significant non-participant is India), and the guidelines lack specificity. The guidelines also lack normative force, as can be seen by the steady growth in global stocks of separated plutonium (Appendix, Table 2).

What might be done: Specific actions for countries to take recommended in this paper include:

- A commitment to keep separation (reprocessing) in balance with consumption (fabrication/use in reactors). To assist in this, states could work on developing guidelines to help determine what "reasonable working stocks" mean in practice. *(The principles of supply/demand balance and limiting surpluses to reasonable working stocks are in INFCIRC/549, but require elaboration.)*

- Ensuring that the rate of reprocessing output is consistent with the capacity to consume such output.

- Exercising due care in authorizing international transfers of plutonium, including assuring that transferred plutonium will be utilized within a reasonable time and will not add to stockpiles in the recipient state. *(This principle is in INFCIRC/549).*

- Medium term: Consuming or disposing of plutonium accumulations; if necessary, consider international collaboration to increase the rate of consumption on a temporary basis.

- Medium term: Taking appropriate actions for management and disposition of excess plutonium from military programs.

Mitigating risks

Risk mitigation for separated plutonium involves consideration of risks from the form and isotopic content of the material and the ways in which it is handled, i.e., the way it is produced, stored, processed, transported, and used. Regarding the form of plutonium, broadly speaking, the level of security risk might be assessed on a spectrum running from weapon-grade plutonium metal through to high-burnup plutonium fabricated as MOX fuel elements. Regarding the handling of plutonium, the number of locations where it is held and used and the number of transport movements, etc., become key factors in assessing and addressing risk.

Another area of risk mitigation is the elimination of non-essential holdings of separated plutonium. In this context *non-essential* refers to separated plutonium not proposed for energy production, where the need for this plutonium no longer applies (e.g., there are no current research uses or other materials could be substituted). Plutonium was less widely used than HEU, but nonetheless was supplied to a number of laboratories around the world, mainly in small quantities but in some cases in much larger quantities for critical assemblies and other research activities. Even small quantities could be of interest to terrorists if they see opportunities for acquiring plutonium in a number of locations.

While there have been long-running international programs aimed at HEU minimization, particularly conversion of U.S. and Soviet-supplied research reactors to LEU and removal of HEU, it is notable that there is no program of equivalent scale for plutonium—although the U.S. Department of Energy's Global Threat Reduction Initiative (GTRI), mainly concerned with HEU, has been active with respect to plutonium.

Current status: A basic problem in considering current status is that only limited information is available on how states handle separated plutonium and on small plutonium holdings. According to the annual reports lodged by participants in the INFCIRC/549 arrangements, at the end of 2013 69% of separated plutonium in civilian programs was held in storage at reprocessing plants, 3% was in the course of fabrication, 13% was in the form of MOX fuel, and 15% was held elsewhere.

What might be done: Specific actions for countries to take recommended in this paper include:

- Committing to convert plutonium into less sensitive forms where technically and economically feasible, and to convert plutonium into MOX fuel as early as practicable, to take advantage of security benefits.

- Minimizing the number of sites with separated plutonium holdings and the number of transport movements of separated plutonium. *(This principle is in INFCIRC/549.)*

- Regularly reviewing the adequacy of security for separated plutonium and developing appropriate mechanisms for providing related assurances.

- Where there is weapon-grade plutonium in irradiated material (e.g., breeder blanket assemblies), avoiding separation that results in a weapon-grade plutonium product (e.g., through in-process blending).

- Identifying non-essential holdings of plutonium and undertaking appropriate actions to deal with these, as has been done for HEU. Actions could include consolidation of holdings (reducing the number of locations), and where possible, removal to the supplier or other suitable state.

- Medium term: Where possible, avoiding production of weapon-grade plutonium.

- Medium term: Where possible, encouraging/developing reprocessing technologies that avoid pure plutonium output.

- Including proliferation-resistance and safeguards-by-design as design objectives for new technologies.

- Facilities already using plutonium or MOX should be encouraged to use excess separated plutonium, or MOX fuels belonging to other utilities or states, where technically and economically feasible.

Vehicles for Implementing Proposals

Establishing a forum for addressing separated plutonium issues

Given the existence of the INFCIRC/549 guidelines, and the fact that its participants encompass

the main plutonium producers and users, with the exception of India, the INFCIRC/549 group would appear to be a good foundation on which a forum could be established, especially if India can be persuaded to join.[8] Currently, however, activities pursuant to INFCIRC/549 are largely limited to publication by the participants of annual statements on their plutonium, and in some cases HEU, holdings. Although the INFCIRC/549 participants have convened for annual consultations in the past, it is understood this group does not function as a regular forum for cooperation or policy coordination at present. Its meetings serve as a forcing function for producing the annual reports and sharing any changes in plutonium management policies. In its annual meetings since 1997, its only substantive actions have been to amend the guidelines to update the reference to "INFCIRC/Rev. 3" to "INFCIRC/225 as revised." There does not appear to be any other forum that readily provides a mechanism for pursuing minimization and risk mitigation issues.

The IAEA has the role of facilitator for the INFCIRC/549 group and could act as facilitator for an INFCIRC/549 forum. The first step would be to gain the support of the members for initiating a dialogue process. Currently the INFCIRC/549 forum is not being used in any dynamic way—turning the group into a coordinating mechanism would represent a major change. This requires key members of INFCIRC/549—the United States, the United Kingdom, France, and Japan—to actively promote this change with other members and the IAEA. Key members might also initiate dialogue with Japan and India on stockpile and utilization issues pending establishment of the forum.

While an INFCIRC/549 forum has some advantages, many other states have an interest in plutonium issues, so there is also a need for a process that allows broader participation. Participation in INFCIRC/549 is open-ended and other states are invited to join, but to date, membership has been focused on including states that have separated plutonium stocks, since the focus of the guidelines is on management of existing stockpiles. The group has not sought out the views of other states that might have an interest but have no stocks. INFCIRC/549 could form the basis of a broader group, or the IAEA could be asked to convene a working group or committee on plutonium management, either in parallel with or in lieu of an INFCIRC/549 forum.

A major function of the proposed forum (or working group/committee) would be to share experience and promote best practice. The forum might also develop a code of conduct, discussed below. A code of conduct could also be a key aspect of promoting best practice.

[8] India has been invited in the past, but has so far declined to join.

Recognizing that domestic or practical factors could make it difficult for some states to achieve a supply/demand balance in the near term, the forum could develop concepts such as placing plutonium stocks under a regional or multinational storage scheme, e.g., as envisaged in the IAEA Statute (Article XII.A.5)—maybe building on the experience of the commercial reprocessors in storing plutonium on behalf of others.

What might be done: Announcement of the establishment of a forum on separated plutonium, or at least the intention to work towards this, prior to or at the 2016 Summit would contribute to international confidence that minimization of stocks and other risk mitigation measures will receive the necessary attention. Outreach to India, in order to ensure participation of all states producing and using plutonium, should be an important aspect of this proposal.

Developing a code of conduct for separated plutonium

A mechanism that the proposed forum or working group/committee might consider is the development of an international code of conduct for plutonium management, building on the principles in INFCIRC/549. Some ideas for elements that might be included in such a code are outlined in the bullet points in the sections above. Those elements currently included in INFCIRC/549 are indicated.

What might be done: Announcement of an international project to develop a code of conduct for separated plutonium would contribute to international confidence that minimization and other risk mitigation measures are being addressed.

Conclusion

Although there is general agreement, reflected in the 2014 Nuclear Security Summit communiqué, on the need to keep stocks of separated plutonium to the minimum level, currently these stocks are continuing to increase. The INFCIRC/549 arrangement should be strengthened and turned into a mechanism for consultation and coordination on this issue and for taking forward other risk mitigation actions with respect to this material. The forum would also develop guidelines, promote best practice, and so on.

It is recommended that INFCIRC/549 participants and other interested states, together with the IAEA, should consult on the issues discussed in this paper, with the object of announcing the strengthening of the INFCIRC/549 forum, or at least progress towards this, at the 2016 Summit. Meanwhile, states should commit to arresting growth in separated plutonium stocks as a

necessary first step in minimizing plutonium stocks and bringing plutonium supply into line with consumption. In addition, non-essential holdings of separated plutonium should be identified and appropriate actions taken to deal with these.

Appendix

Table 1: Civilian stocks of separated plutonium (tonnes)

End 2003				End 2013		
	A. Holdings in-country	**B. Holdings in other countries**	**C. Holdings for others (incl in A)**	**A. Holdings in-country**	**B. Holdings in other countries**	**C. Holdings for others (incl in A)**
Belgium	3.5	0.4	n.a.	1.4		1.3
France	78.6		30.5	78.1		17.9
Germany	12.5	13.5		3.0	3.8	
India	1.5			2.5		
Japan	5.4	35.2		10.8	36.3	
Russia	38.2			51.9		
USA	45.0			49.0		
UK	96.3	0.9	22.5	123.0		23.4
Others		6.1				
Total (rounded)	**281.0**	56.1	53.0	**319.7**	40.1	42.6

Sources: National INFCIRC/549 reports (except for India which does not participate), supplemented by ISIS *Plutonium Watch*, August 2005, ISIS *Civil Plutonium Stocks Worldwide, End of 2013*, and some breakdowns from International Panel on Fissile Materials website, http://www.fissilematerials.org

Table 2: World commercial reprocessing capacity (tonnes pa)

	Tonnes spent fuel	**Max plutonium output (est)**
France – La Hague	1,700	12
UK – Sellafield (THORP)(a)	600	8.5
Sellafield Magnox (b)	1,500	2.5
Russia – Ozersk (Mayak)	400	3.2
Japan – Rokkasho (c)	800	7
India – 4 plants	330	1.3
	5,370	**34.5**

Notes: (a) shut down planned for 2018.
(b) shut down planned as soon as practicable.
(c) start-up planned for 2016, reaching full capacity by 2019.

Sources: World Nuclear Association September 2014, plutonium output based on author's calculations.