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VIEWPOINT

All hands on deck: advancing safeguards for naval nuclear materials

Andrew W. Reddie and Bethany L. Goldblum

ABSTRACT
With the continued use of unsafeguarded naval nuclear-propulsion programs in all nuclear-weapon states, the commissioning of an Indian nuclear submarine, and the potential investment in such programs by non-nuclear-weapon states including Brazil and South Korea, movement toward a regulatory regime for nuclear material in the naval sector has become imperative. Such a framework faces a recurring debate on adequately protecting sensitive military technology while delivering assurances that naval nuclear material is not diverted to nuclear-weapon programs. In this viewpoint, we examine various prospective mechanisms to regulate naval nuclear stocks and assess them in terms of their effectiveness and scope. Drawing on lessons from the drafting, negotiation, and implementation of the Model Additional Protocol, we recommend a safeguards regime for naval nuclear material via a protocol that supplements the existing global nuclear-governance system. This protocol provides a standardized yet flexible approach to naval nuclear-material safeguards across all states (whether nuclear-weapon states, non-nuclear-weapon states, or outside the Treaty on the Non-Proliferation of Nuclear Weapons) to handle variations among naval nuclear fuel cycles and technologies.

KEYWORDS
safeguards; naval nuclear materials; nuclear propulsion; nuclear submarines; Brazil; South Korea; fissile materials; highly enriched uranium

According to the 2015 Global Fissile Materials Report, more than 150 metric tons of highly enriched uranium (HEU) has been designated for use in the naval sector, primarily in the United States and Russia.[1] Assuming that an adequate quantity of nuclear material for a simple gun-type nuclear device is 25 kg of U-235, the primary fuel for HEU-based nuclear weapons, current naval stocks may represent more than one thousand nuclear weapons worldwide.[2] Given the substantial amount of nuclear material in the naval sector, the lack of safeguards on this material poses a proliferation and material security

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[1] "Global Fissile Material Report 2015," International Panel on Fissile Materials, Princeton, NJ, December 2015, <http://fissilematerials.org/library/gfmr15.pdf>.

[2] The use of 25 kg as the approximate amount of U-235 in HEU to enable the manufacturing of a nuclear explosive device is based on the IAEA's "significant quantity" standard. Significant quantities take into account unavoidable losses due to conversion and manufacturing processes and should not be confused with critical masses. This calculation further assumes 20 percent enriched naval fuel as a conservative estimate. The estimated number of nuclear weapons reflected by naval stocks could increase substantially if considering a sophisticated implosion design, advanced manufacturing processes, and higher-enriched stocks. See James Martin Center for Nonproliferation Studies at the Middlebury Institute of International Studies, "Civilian HEU Reduction and Elimination Resource Collection," Nuclear Threat Initiative, October 12, 2016, <www.nti.org/analysis/reports/civilian-heu-reduction-and-elimination/>; Thomas B. Cochrane and Christopher E. Paine, "The Amount of Plutonium and Highly-Enriched Uranium Needed for Pure Fission Weapons," National Resources Defense Council, April 13, 1995, <www.ambienteparco.it/pdf/fissionweapons.pdf>

risk. Moreover, India's commissioning of the nuclear submarine INS *Arihant*, Iran's plan to establish a nuclear-propulsion capability, South Korea's renewed interest in a nuclear navy, and Brazil's program to develop nuclear-powered attack submarines suggest that the time is ripe to consider how to decrease the risk of weaponizing naval nuclear material.[3] Policy makers should update global nuclear-governance frameworks to reflect these emerging challenges. Further, this regulatory effort—and specifically effort toward a new Supplementary Protocol (SP) shaped after the Model Additional Protocol (MAP)—may lead to solutions for a problem that has been mostly ignored by the international community.

Under the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (NPT), comprehensive safeguards agreements (CSAs) concluded on the basis of INFCIRC/153 (Corrected) provide a legally binding instrument designed to deter the diversion of nuclear materials to nuclear-weapon uses through a system of audits and inspections.[4] However, CSAs do not apply to all states, in particular states recognized as "nuclear-weapon states" (NWS) under the treaty (China, France, Russia, the United Kingdom, and the United States) and no criteria exist to determine when nuclear materials fall under an exempted category, "non-proscribed military activity."[5] Under that clause, non-nuclear-weapon states (NNWS) can request that nuclear material produced indigenously or without explicit supplier restrictions be exempted from International Atomic Energy Agency (IAEA) safeguards for use as fuel in naval reactors. Solutions in the existing literature for preventing diversion of such material to nuclear weapons uses tend to focus on closing the gap posed by paragraph 14 of INFCIRC/153 (Corrected)—the IAEA document specifying the requirements for safeguards under CSAs; that paragraph outlines the procedures that a NNWS must follow if it "intends to exercise its discretion to use nuclear material which is required to be safeguarded in a nuclear activity which does not require the application of safeguards under the Agreement."[6] However, this paragraph applies neither to NWS, where the vast majority of current naval stocks lie, nor to non-NPT-signatory nuclear-capable states, and it does not set strict conditions for alternative mechanisms that might be used to monitor such materials against diversion to weapons.

NWS often thwart efforts to engage in cooperative action to regulate naval nuclear stocks with concerns over protecting sensitive military information and technology. Proliferation risk assessments mostly focus on enrichment and reprocessing facilities, which are widely recognized as having the lowest proliferation barriers on the pathway to a weapon capability.[7] By drawing on existing scholarship, we develop a typology of the naval nuclear fuel cycle which focuses on the interplay between proliferation

[3] Mark Hibbs, "Iran Nuclear Propulsion: IAEA Firewalls," Carnegie Endowment for International Peace, January 4, 2017, <http://carnegieendowment.org/2017/01/04/iran-nuclear-propulsion-iaea-firewalls-pub-66603>; Lami Kim, "Has South Korea Renounced 'Nuclear Hedging'?" *Bulletin of the Atomic Scientists*, June 27, 2017, <http://thebulletin.org/has-south-korea-renounced-"nuclear-hedging"10863>; Park Byong-Su and Lee Jung-ae, "Debate Continues on Whether South Korea Should Acquire SSN Nuclear Submarines," *The Hankyoreh*, September 21, 2017, <http://english.hani.co.kr/arti/english_edition/e_national/812008.html>.

[4] IAEA, "The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons," INFCIRC/153, June 1972.

[5] For more on the extant problems associated with the contemporary global naval nuclear-governance architecture, see Jeffrey Kaplow, "The Canary in the Nuclear Submarine: Assessing the Nonproliferation Risk of the Naval Nuclear Propulsion Loophole," *Nonproliferation Review*, Vol. 22, No. 2 (2015), pp. 185–202.

[6] Justin Alger, "A Guide to Global Nuclear Governance: Safety, Security and Nonproliferation," Centre for International Governance, September 2008, <www.cigionline.org/sites/default/files/a_guide_to_nuclear_power.pdf>.

[7] National Research Council, *Improving the Assessment of the Proliferation Risk of Nuclear Fuel Cycles* (Washington, DC: National Academies Press, 2013), p. 35.

pathway assessments and information sensitivity. This enables us to outline a path toward the regulation of naval nuclear material which circumvents classification concerns by identifying safeguards opportunities in high-risk, low-sensitivity naval fuel-cycle stages.[8] This work is necessary given that existing scholarship calling for increased and "managed access" to naval bases has thus far underestimated the challenges that would be posed by inspector access to naval bases, due to the high information value associated with these installations.[9] Rather than focusing on managed access to overcome information sensitivity, we build a tiered safeguards system that would allow consensus to be built among various types of states. Indeed, we posit that states may be more inclined to join the future Naval Nuclear Materials Committee (NNMC) that we propose or to sign a minimally intrusive protocol rather than agree to a managed access provision. Moreover, we consider all states in the system rather than solely NNWS. In this analysis, we leverage the institutional framework of the existing nuclear nonproliferation regime and lessons from historical efforts to enhance safeguards and verification with the goal of decreasing the global risk posed by naval nuclear materials while mitigating concerns over sensitive military information associated with naval nuclear propulsion.

Though the weaponization of naval nuclear materials is not currently an existential threat, the safeguarding of naval nuclear stocks across all types of state actors would be a desirable outcome. Just as the MAP strengthened the standard for all states with IAEA safeguards agreements, standard guidelines for safeguards agreements surrounding the naval nuclear fuel cycle reinforce the IAEA's ability to verify the peaceful use of nuclear materials more broadly. Acting now rather than waiting for the diversion of naval nuclear material to nuclear weapons or other nuclear-explosive devices will bolster the safeguards regime and mitigate potential crisis scenarios. This viewpoint answers two interrelated questions concerning the future of the global nuclear governance: How should states address the unregulated use of naval nuclear material? And what is the optimal mechanism for safeguarding naval nuclear materials within the existing NPT framework?

Classification of states in the global nuclear nonproliferation regime

There are four categories of states in the nuclear safeguards space which policy makers must address.

First, there are the five acknowledged NWS under the NPT, noted earlier, all of which have concluded Voluntary Offer Agreements (VOAs) allowing IAEA safeguards on some or all of their civilian nuclear installations.[10] Second, there are NNWS that are obliged under the NPT to place all of their nuclear material under IAEA safeguards. As part of this obligation, these states are required to conclude CSAs, typically based on INFCIRC/153 (Corrected), with the IAEA.[11] As noted earlier, INFCIRC/153 (Corrected)

[8] Sébastien Philippe, "Safeguarding the Military Naval Nuclear Fuel Cycle," *Journal of Nuclear Materials Management* Vol. 42, No. 3 (2014), pp. 40–52; Nick Ritchie, "The UK Naval Nuclear Propulsion Programme and Highly Enriched Uranium," FAS Task Force on Naval Nuclear Reactors, February 2015.

[9] Ibid.

[10] NPT, July 1, 1968.

[11] Alternatively, NNWS states can also pursue regional agreements that have equivalent declarations concerning the peaceful use of nuclear energy and safeguards. The Brazilian–Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) created in 1991 serves as an example of such an arrangement. The relationship between Brazil, Argentina, ABACC, and the IAEA was subsequently formalized via the Quadripartite Agreement (INFCIRC/435) that entered into force in 1994.

contains a provision in paragraph 14 which governs the processes by which materials under safeguards may be withdrawn for use in a non-prohibited military activity (such as naval propulsion). Third, there is one state without nuclear weapons that is a non-signatory to the NPT: South Sudan. And, fourth, there are four nuclear-armed states outside of the NPT regime—India, Israel, Pakistan, and North Korea.[12] While these states have not signed the NPT, the first three—India, Israel, and Pakistan—have concluded legally binding item-specific safeguards agreements with the IAEA under INFCIRC/66/Rev.2, which apply safeguards to certain civilian nuclear facilities.[13]

As outlined above, the paragraph 14 framework applies solely to one of the four categories of states—NNWS with CSAs. Given that nuclear navies are increasingly on the agenda for three out of the four categories of nations (NWS, NNWS, and nuclear-armed states outside the NPT regime), future solutions should be predicated on solving the naval nuclear material risk universally, for all types of states. Indeed, there may be added virtue (beyond material security and risks of misuse) in including the NPT NWS in such a regulatory regime, because, if they embrace some form of voluntary restraint, this might advance the concept of restraints more broadly. Such engagement may also serve to underscore their nuclear disarmament commitments under Article VI of the NPT.

Regulatory mechanisms

Prospective policy solutions designed to regulate the use of naval nuclear materials exist both within and outside of the NPT framework with state-centric, bilateral, and multilateral options. These ideal-typical solutions including NWS policy statements, bilateral démarche mechanisms, multilateral codes of conduct, IAEA interpretation of paragraph 14, and an IAEA Supplemental Protocol, are summarized in Table 1 and described in greater detail below. Each of the five proposed policy options exists on a continuum between "soft" (non-binding) and "hard" (binding) regulation, and, while some can be used in isolation, others are not mutually exclusive. Moreover, "softer" options also have the potential to set the groundwork for "harder" regulations as building blocks toward a stronger nonproliferation and disarmament regime. This list is not designed to be exhaustive. While more restrictive governance options for regulating naval nuclear materials may evolve, such as through a Fissile Material Cutoff Treaty (FMCT)—not yet under negotiation—or the Treaty on the Prohibition of Nuclear Weapons—not yet in force—this viewpoint focuses on those mechanisms considered most feasible within the current political climate.[14]

Each of the regulatory mechanisms listed in Table 1 is described in greater depth below.

[12] North Korea first ratified the NPT in December 1985, before announcing its intention to withdraw in March 1993 and finally doing so in April 2003. This withdrawal followed allegations from the United States that North Korea was illegally enriching uranium for use in weapons.

[13] For more on item-specific agreements, see Cristian DeFrancia, "The Continuing Role of Item-Specific Agreements in the IAEA Safeguards System," *Nuclear Law Bulletin*, Vol. 2011, No. 2 (2012), pp. 37–59; IAEA, "The Agency's Safeguards System," INFCIRC/66/Rev.2, September 1968.

[14] On the challenges facing global disarmament and the FMCT, see Jonathan Pearl, *Forecasting Zero* (Charleston, SC: CreateSpace, 2015). The United States, for its part, has repeatedly stated that an FMCT would apply to material for nuclear weapons, omitting any reference to propulsion and other potential military uses. For an analysis of how different FMCT provisions could impact naval nuclear materials, see Marion Burgess, Jr., "The Proposed Fissile Material Cutoff Treaty (FMCT) and Its Potential Impact on U.S. Navy Nuclear Propulsion Programs" thesis, Naval Postgraduate School, 2010. While the 2017 Treaty on the Prohibition of Nuclear Weapons does not directly address naval nuclear stocks and has not been recognized by any nuclear-armed states, it may have a reciprocal effect to catalyze the management of nuclear materials use in non-proscribed military activities. For further information, see Rick Gladstone, "U.N. Panel

Table 1. Policy options for decreasing the risks posed by fissile nuclear materials in the naval sector

	Policy option	Description
1	NWS policy statement	Declaratory policy by a single NWS encouraging regulation of naval nuclear materials
2	Bilateral démarche	Formal statement issued bilaterally by one state to another requesting the safeguarding of naval nuclear materials or protesting naval nuclear-materials handling
3	Multilateral code of conduct	Non-binding mechanism to establish global behavior norms and regulations
4	IAEA action (GOV/INF or INFCIRC)	Statement by the IAEA director general representing the views of the Board of Governors and the Secretariat on paragraph 14 terms and procedures (GOV/INF) and reproduced for all members in the form of an information circular (INFCIRC)
5	IAEA SP	Legal document addressing naval nuclear materials which supplements states' existing IAEA safeguards agreements

NWS policy statement

A call to action led by a significant actor in global nuclear governance—such as the United States, China, or France—could drive the conversation surrounding the regulation of naval nuclear material. For an NWS, a policy statement on safeguarding the naval nuclear fuel cycle offers benefits by signaling to neighbors and other major powers a commitment to reducing the risk of nuclear proliferation and ensuring naval stocks are not used in a nuclear-weapon program. Such an action may further drive policy and scientific innovation in naval nuclear material safeguards as well as research and development toward decreasing the risks posed by these materials, such as low-enriched-uranium (LEU) naval reactor core design.[15]

NWS also have a particularly significant role to play in modeling appropriate behavior toward safeguards. The recent UK–Norway Initiative on the Verification of Nuclear Warhead Dismantlement offers an example of a collaboration between an NWS and NNWS to address critical matters of nuclear security.[16]

However, a disadvantage lies in the lack of teeth; policy statements are a non-binding mechanism that may not influence other states to follow suit. And it appears unlikely—given the information sensitivity concerns outlined above—that a NWS will take the lead and demand that the nuclear-policy community and associated institutions address the challenge presented by naval nuclear material.

Releases Draft Treaty to Ban Nuclear Arms," *New York Times*, May 22, 2017, <www.nytimes.com/2017/05/22/world/americas/united-nations-nuclear-weapons.html>; Rick Gladstone, "A Treaty Is Reached to Ban Nuclear Arms. Now Comes the Hard Part," *New York Times*, July 7, 2017, <www.nytimes.com/2017/07/07/world/americas/united-nations-nuclear-weapons-prohibition-destruction-global-treaty.html>; James Martin Center for Nonproliferation Studies, "Proposed Nuclear Weapons Ban Treaty," Nuclear Threat Initiative (NTI), <www.nti.org/learn/treaties-and-regimes/proposed-nuclear-weapons-ban-treaty/>.

15 George Moore, "Life-of-Ship Reactors and Accelerated Testing: On Naval Propulsion Fuels and Reactors," Federation of American Scientists, Special Report, March 2017, <https://fas.org/pub-reports/life-of-the-ship-reactors-and-accelerated-testing-of-naval-propulsion-fuels-and-reactors/>; Alain Tournyol du Close, "France's Choice for Nuclear Propulsion: Why Low-Enriched Uranium Was Chosen," Federation of American Scientists, Special Report, December 2016, <https://fas.org/pub-reports/frances-choice-for-naval-nuclear-propulsion-why-low-enriched-uranium-was-chosen/>.

16 Ase Marie Fossum, "UK–Norway Initiative on Nuclear Warhead Dismantlement Verification: A NWS–NNWS Cooperation," presentation delivered at the Moscow Nonproliferation Conference, Moscow, March 5, 2010; Elin Enger, "The Challenge of Verification: The UK–Norway Initiative on Non-Nuclear-Weapon States' Participation in the Verification of Nuclear Disarmament," working paper delivered at the Warsaw Workshop: Prospects for Information Sharing and Confidence Building on Non-Strategic Nuclear Weapons in Europe, Warsaw, February 7–8, 2013.

Bilateral démarche

More robust than a call to action, the use of a bilateral démarche offers an alternative diplomatic mechanism by which states can address the gap in the regulation of naval nuclear materials—at least on a bilateral basis—where the lack of safeguards on naval nuclear stocks poses a risk to international security. States can use the démarche process to persuade, gather information, and inform other states of their respective interests as well as to protest and object to actions taken by other states and institutions via diplomatic notes. This process also allows for the creation of an aide-mémoire that contains written points and demands to be addressed. The démarche process is flexible in that each state can customize it as needed, and that it does not require significant changes to the contemporary regulatory regime given the dyadic nature of the communication. The United States, for example, might approach Brazil or, should it pursue nuclear propulsion, South Korea, urging that this country establish effective mechanisms for providing assurance that nuclear materials are not diverted to weapons uses.

The major advantages of this process are its flexibility, availability, and speed, as all states have the opportunity to use this existing diplomatic protocol to quickly address a pressing regulatory problem and can do so during the course of normal communications with ambassadorial staff. In addition, support for using such a process from state actors is likely to be simple, as the démarche process is nominally private. However, there are a number of disadvantages. First, because the communication is private, practices called for in the aide-mémoire are unlikely to spread beyond the states subject to the démarche or to civil society. Second, the bilateral démarche process leaves out other players that might provide alternative, improved solutions to a given regulatory challenge while also eschewing the advantages of extant multilateral, regulatory institutions such as the IAEA. And, third, a démarche's ability to facilitate regulatory standards or norms is reduced by the inherent informality of the process. Given the long-term impacts of regulatory solutions to nuclear challenges, such a stopgap measure is limited in terms of its potential effectiveness.

Multilateral, non-binding code of conduct

Multilateral, non-binding codes of conduct (CoC) relating to the naval use of nuclear materials could surmount the information barrier of the démarche process and provide a non-binding mechanism through which players agree to specific standards of behavior. Such a framework offers a best-practices approach to this global-governance challenge while obviating the difficulties associated with a formalized treaty. Indeed, such voluntary codes have been used throughout global-governance regimes to deal with challenges surrounding human rights, corporate supply chains, and the weaponization of technology.[17] And, while some scholars remain skeptical of their utility, "soft law" has distinct advantages under conditions in which states have cause to guard their autonomy.[18] Further, as noted above, these "soft" approaches can lay the groundwork for future agreements

[17] For more on the role of voluntary codes in corporate supply chains, see Debora Spar, "The Spotlight and the Bottom Line: How Multinationals Export Human Rights," *Foreign Affairs*, Vol. 77, No. 2 (1998), pp. 7–12.

[18] Kenneth Abbott and Duncan Snidal, "Hard and Soft Law in International Governance," *International Organization*, Vol. 54, No. 3 (2000), pp. 421–56.

to evolve while also allowing a larger number of actors than might otherwise do so participate within a "hard" or binding framework.

A CoC relating to the safeguarding of naval nuclear materials might allow each state to independently arrive at a safeguards process that best matches its needs based on an overarching code rather than a one-size-fits-all solution. For example, a CoC for naval nuclear material might read, "All states agree to maintain appropriate regulatory standards for nuclear materials in the naval sector to address the risk of a state diverting nuclear material." This language, modeled on the IAEA Convention on the Physical Protection of Nuclear Material relating to nuclear security, recognizes the importance of protecting nuclear material from theft or misuse by a non-state actor by providing a legally binding mechanism for addressing nuclear material in peaceful use.[19]

Moreover, a CoC is already used within the existing global nuclear-governance architecture. The Code of Conduct on the Safety and Security of Radioactive Sources approved by the IAEA's Board of Governors provides a non-binding mechanism that seeks "the development and harmonization of policies, laws, and regulations on the safety and security of radioactive sources."[20] The 2003 revision of the Code further includes provisions addressing nuclear terrorism following the September 11, 2001 events in the United States. While states are not required to harmonize their policies, the IAEA General Conference urged states to write to the director general expressing their support for the Code. The IAEA has also developed non-binding guidance on the import and export of radioactive sources.[21]

One advantage of the CoC framework is that it sets out specific, desirable outcomes without placing limitations on the process of getting there, while at the same time leveraging institutional expertise provided by international organizations. This allows states the political space to engage in preliminary talks concerning a more permanent agreement, treaty, or institution while signaling that specific behaviors are acceptable or unacceptable.[22]

However, while a CoC avoids the political costs associated with a binding agreement, amendments in a changing technological sector are difficult to prescribe in CoCs, which in general lack verification or enforcement mechanisms. The lack of teeth may also lead to the degradation of the regulatory regime over time if no progress is made on more permanent agreements. Perhaps most importantly, states can fail or refuse to comply with the CoC with little to no cost, undermining the regulatory regime.[23] As such, CoCs may be a useful starting point for safeguarding naval nuclear materials but are likely insufficient to address the risks posed by the specific vulnerabilities of the naval nuclear sector.

[19] George Bunn, "Brief History of NPT Safeguards Article," Pacific Northwest National Laboratory, February 6, 2006, <http://cgs.pnnl.gov/fois/doclib/NPTNegHist.Art.III.6%20Feb.06.pdf>; Walter Gehr, "The Universal Legal Framework Against Nuclear Terrorism," *Nuclear Law Bulletin*, Vol. 2007, No. 1 (2007), pp. 5–15.

[20] IAEA, "Code of Conduct on the Safety and Security of Radioactive Sources," IAEA/CODEOC/2004, January 2004.

[21] IAEA, "Guidance on the Import and Export of Radioactive Sources," IAEA/CODEOC/IMO-EXP/2012, May 2012.

[22] For more on the socialization mechanism, see Judith Kelley, "International Actors on the Domestic Scene: Membership Conditionality and Socialization by International Institutions," *International Organization*, Vol. 58, No. 3 (2004), pp. 425–57.

[23] For an account of the academic debate surrounding compliance, see Kal Raustiala and Anne-Marie Slaughter, "International Law, International Relations and Compliance," in Walter Carlsnaes, Thomas Risse, and Beth Simmons, eds., *The Handbook of International Relations* (Thousand Oaks, CA: Sage, 2002), pp. 538–58.

IAEA action: GOV/INF or information circular (INFCIRC)

Given these vulnerabilities, the IAEA may be the proper source for clarifications concerning appropriate regulation of naval nuclear material. The lack of clarity concerning paragraph 14 of INFCIRC/153 (Corrected), however, was evidenced when, in 1978, Australia sponsored a note to the Director General querying the appropriate pathway for states to transition nuclear material from safeguards to non-proscribed use.[24] In response, Director General Sigvard Eklund made clear that, as of July 1978, the Board had "not had occasion to interpret that paragraph, nor has it elaborated in further detail the procedures to be followed pursuant to that paragraph."[25] Eklund went on to note that a state exercising its discretion under paragraph 14 "must be reported to the Board of Governors, and it would be for the Board of Governors in each case to take the appropriate action."[26] In the intervening thirty years, there has been no systematized approach by the Board to the challenges posed by material being designated for non-proscribed use. New guidance relating to governance via IAEA action offers an opportunity for the Agency to detail the guidelines and procedures for a state transferring nuclear material from safeguards to non-proscribed military use. This response could take the form of a GOV/INF or an INFCIRC made universally available to all members of the IAEA.[27]

Either mechanism would provide the director general's interpretation of the paragraph 14 "loophole" language, and in turn establish norms of behavior for those states seeking to withdraw nuclear material designated for use in a non-proscribed military activity.[28] A GOV/INF, specifically, would deal with the withdrawal of nuclear material from safeguards on a case-by-case basis as states write to the Board of Governors and the director general invoking paragraph 14. The Board's response would then allow for a state-specific but precedent-setting response to the challenges posed by an individual state.

Rather than dealing with paragraph 14 on a case-by-case basis, the Secretariat and Board might also provide general guidelines and procedures concerning its invocation. This process could be initiated by a member state or group of states invoking paragraph 14 or sponsoring a note to the director general and/or Board of Governors requesting guidance on the withdrawal of nuclear material from safeguards under paragraph 14—in a manner similar to Australia's 1978 letter mentioned above. Such an action might precipitate the issuance of a public document, or INFCIRC, to inform all NNWS with comprehensive safeguards agreements subject to INFCIRC/153 (Corrected) of their respective

[24] The correspondence between the Australian government and the Director General can be found in IAEA, "The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons," GOV/INF/347, 3 July 1978.

[25] "The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons," GOV/INF/347, 3 July 1978.

[26] Ibid.

[27] A GOV/INF document is prepared by the Secretariat and submitted by the director general to the Board of Governors to inform the Board of an issue and suggest a course of action. The director general may be involved in the drafting and may approve the text before it is distributed to the Board. An INFCIRC (Information Circular) is a document that has been approved and adopted by the Board and is circulated to member states.

[28] This mechanism for regulating naval stocks would be similar to the process initiated by Canada's pursuit of a nuclear submarine program in the 1980s. In this case, Canada consulted the IAEA Director General for guidance on removing nuclear material from safeguards under paragraph 14 for use in a naval nuclear program. No formal arrangement was brokered, as Canada ultimately did not pursue the program, and thus no formal guidelines were established. For more on Canada's negotiations with the IAEA, see Marie-France Desjardins and Tariq Rauf, "Opening Pandora's Box? Nuclear-Powered Submarines and the Spread of Nuclear Weapons," Canadian Center for Arms Control and Disarmament (Aurora Papers 8), 1988.

safeguard responsibilities. This approach would then establish the interpretation of paragraph 14 and set terms and provisions within the IAEA for the safeguarding of naval nuclear materials.

Relying on decision making by IAEA leadership rather than country negotiation via a deliberate coordinated process, however, presents clear challenges. First, the lack of systematized state involvement in establishing guidelines regarding paragraph 14 might fundamentally undermine compliance with the regime—particularly with regard to verification and enforcement. While GOV/INF 347 clearly provides the director general with the mandate to manage INFCIRC/153 (Corrected), NWS would undoubtedly provide feedback concerning appropriate regulations. As a consequence, the format for member state negotiations surrounding regulation in this capacity is unclear. Second, this approach is limited insofar as it addresses only those issues raised by member states in their communication with the Board within the existing legal framework and, as such, may leave loopholes in existing regulation. Third, explicit naval nuclear safeguards guidelines solely within the scope of paragraph 14 leave gaps in enforcement for those states currently outside of the NPT or not subject to INFCIRC/153-type obligations. As a result, this policy option represents an incomplete solution to the challenges presented by nuclear navies.

IAEA supplemental protocol

To address some of the concerns above, we suggest that a standard—in the sense that it applies to all states—supplemental protocol (SP) may provide a legally binding framework to address the extant gap in the security of naval nuclear materials. Such a framework offers the most comprehensive approach of the regulatory mechanisms examined in this paper. Akin to the Model Additional Protocol and building on the Naval Use Safeguards Agreement developed by the University of California, Berkeley's Naomi Egel, Bethany Goldblum, and Erika Suzuki, this mechanism supplements existing IAEA safeguards agreements with protocols for naval nuclear materials.[29] Rather than an approach that calls for mandatory regulations for NNWS and confidence-building measures for NWS, the SP represents a mutually agreeable framework via a tiered safeguards solution that builds upon the existing architecture. It is designed to add to extant safeguards agreements in all three relevant categories of states noted above, whether they have an INFCIRC/153-type agreement or not. As with the MAP, an ad hoc committee of the Board could be established to draft an SP addressing the application of safeguards in the naval nuclear sector. The text could then be approved by the Board and agreed upon by individual states. The mechanism, explained in greater detail below, could also take advantage of existing institutions—such as the Nuclear Suppliers Group—to bolster the regulatory regime and more broadly establish parameters surrounding the use of nuclear material for non-proscribed military use.[30] This framework would allow,

[29] Naomi Egel, Bethany Goldblum, and Erika Suzuki, "A Novel Framework for Safeguarding Naval Nuclear Material," *Nonproliferation Review*, Vol. 22, No. 2 (2016), pp. 239–51.

[30] Civilian nuclear cooperation between states has contributed to the proliferation of nuclear material and technologies. Thus, the matching of the Trigger List and Dual Use "Guidelines" included in INFCIRC/539/Rev. 2 with any new SP would be necessary. Moreover, the inclusion of a requirement to sign onto the SP—akin to the recent requirement to sign onto the MAP for membership in the Nuclear Suppliers Group (NSG)—in order to apply for nuclear technology transfers might provide a pathway toward widespread acceptance of the SP process. For more on the transfer of nuclear

for example, a discussion among states regarding the appropriate export controls pertaining to nuclear-submarine and naval reactor technologies given that all existing nuclear-submarine programs—with the exception of the United States'—have hitherto benefited from direct or indirect aid.[31]

An SP would include physical safeguards measures and improved administrative arrangements for material in the naval nuclear fuel cycle. A flexible framework, the SP would be applicable for both HEU- and LEU-based naval propulsion systems and relevant for all states regardless of their nuclear-weapon status or existing safeguards agreements. Although the likelihood that states would converge on a mutually agreeable SP remains debatable in light of national-security concerns, a flexible framework has the potential to facilitate a universally acceptable solution. We argue in the sections below that an SP offers the most viable solution for establishing naval nuclear-material safeguards.

An SP solution

The negotiation of an SP would be the most appropriate path for establishing a new regulatory framework for naval nuclear material. Relevant states parties having any of the three types of safeguards agreements—VOAs, CSAs, or item-specific agreements—are placed in the seat of authority while relying on institutional expertise and legal precedence emanating from the existing safeguards regime. Such a course of action balances the need for a universal, standardized, and legally binding framework as well as the tensions associated with military sensitivities, to provide an avenue for progress in addressing the risks posed by naval nuclear materials as described below.

Standardized structure for all states

Building on the precedent set by the negotiation of the MAP, an SP for naval safeguards would be standardized and flexible in terms of specific safeguarding mechanisms, naval fuel-cycle types, and facilities across signatories. Indeed, the SP would be standard in that it would include states beyond NNWS via the creation of agreed-upon safeguards provisions for naval nuclear facilities. Further, the SP would be flexible insofar as states differentially engaged with the provisions of the SP based on their particular fuel cycle, reactor design characteristics, facilities, and perceptions of national security. This standard and flexible approach brings all states under a single regulatory architecture, thereby raising the standard for safeguarding nuclear material.

The Committee 24 negotiations in 1996 relating to the establishment of MAP measures to strengthen safeguards provide key lessons concerning standardization. Initially, the INFCIRC/66 states—Cuba, Israel, Pakistan, and India—refused any application of additional safeguards to themselves. The NWS eventually pledged to accept at least some measures on a voluntary basis and NNWS expressed concern about adhering to the protocol lest NWS obtain an industrial advantage. The final implementation of the

technology, see Matthew Fuhrman, "Taking a Walk on the Supply Side: The Determinants of Civilian Nuclear Cooperation," *Journal of Conflict Resolution*, Vol. 53, No. 2 (2009), pp. 181–208; Matthew Kroenig, "Importing the bomb: Sensitive nuclear assistance and nuclear proliferation." Journal of Conflict Resolution, Vol. 53, No. 2 (2009), pp. 161–80.

[31] James Clay Moltz, "Closing the NPT Loophole on Exports of Naval Propulsion Reactors," *Nonproliferation Review*, Vol. 6, No. 1 (1998), pp. 108–14.

MAP required states with CSAs to accept all provisions of the MAP, while states with item-specific safeguards or VOAs were left to implement measures of their choosing. The United States, for example, accepts all of the measures of the protocol, with the usual national-security exception.

A similar political landscape should be expected in naval-use negotiations, and the support and engagement of the NWS are crucial in this regard. Establishing a model protocol that engages all states, regardless of nuclear-weapon status, circumvents the perception of discrimination resulting from the NPT's different categories of states. Importantly, this standardized structure institutionalizes the goal of preventing the weaponization of nuclear material designated for naval use by state parties. The success of such a mechanism in safeguarding military installations would likely be heavily dependent on NWS engagement and leadership.

Flexibility based on information sensitivity

The negotiation of an SP also allows states the flexibility to implement different measures of the protocol based on their national-security concerns and the design of their non-proscribed military programs. Put in simple terms, the SP would provide a safeguards template while allowing states to customize specific safeguards measures based on their specific naval nuclear fuel cycle, design characteristics, and facilities. In particular, such a regime would seek to address the challenges associated with sharing sensitive information. To analyze this issue, we present a schematic of the naval nuclear fuel cycle, shown in Figure 1, where a color scale is used to indicate varying degrees of military sensitivity. Military sensitivity here is a measure of the barrier to safeguards implementation, taking into account both information sensitivity and the feasibility of technical measures that preserve confidentiality. Blue represents those activities that have lower sensitivity (e.g., higher safeguards feasibility), orange those with moderate levels of sensitivity, and

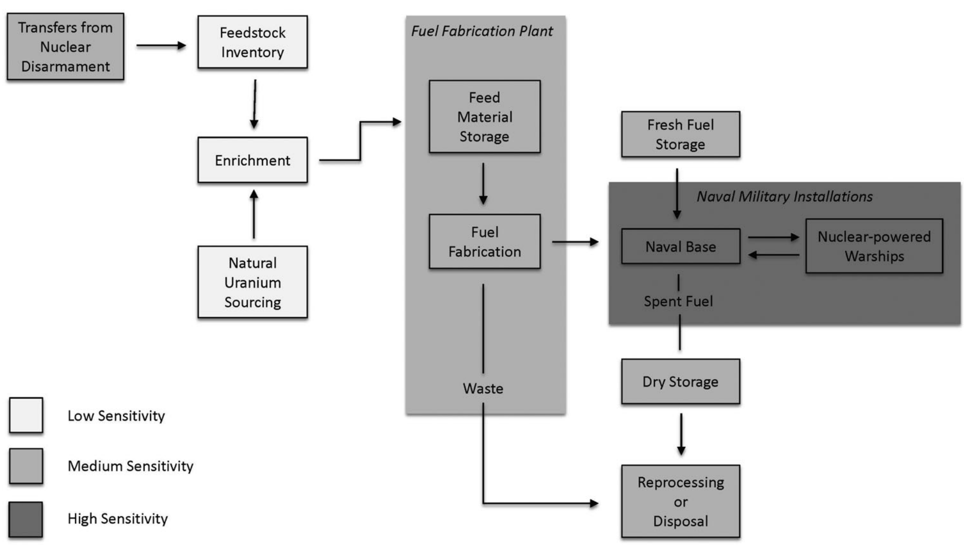

Figure 1. The naval nuclear fuel cycle.

green those activities with higher levels of sensitivity (e.g., lower safeguards feasibility). In reality, there is a continuum of sensivity rather than clear-cut distinctions at the different stages of the naval nuclear fuel cycle. This graphic is not meant to suggest that these categories provide absolute distinctions. The sensitivity of a particular installation will vary based on a state's own evaluation of the degree to which information disclosure associated with that stage would damage its national security and the risks associated with specific safeguard measures purported to protect information and activities. These notional categories capture broad trends and suggest that a tiered approach toward regulating naval nuclear materials might offer the most propitious path forward.

In this schematic, the naval nuclear fuel cycle mirrors the civilian fuel cycle until the fissile material is transferred to a naval base; the "low sensitivity" and "moderate sensitivity" parts of the fuel cycle (in blue and orange, respectively) are thus similar to a civilian fuel cycle. Activities involving the procurement of natural uranium and isotopic enrichment are grouped under "low sensitivity" and noted in blue. This material in NNWS is already largely under safeguards through INFCIRC/153 (Corrected) and the MAP for those states that have signed it.[32] Similarly, safeguards have also been applied to civilian facilities within these stages for states with item-specific agreements or VOAs. For naval nuclear installations, there is lower information-sensitivity concern in these stages, as fuel enrichment by naval reactor type and model is available in the open literature.[33] As verification at these stages presents no new technological or procedural challenges, this subset of activities represents a lower barrier for standardized implementation of naval safeguards regulations in all three relevant categories of states.

The information sensitivity associated with safeguards increases during material transfers from nuclear disarmament and fuel-fabrication activities, which have moderate sensitivity as noted in orange. A moderate rating is assigned here based on the degree to which the material reveals nuclear weapons or naval reactor design information and the feasibility of safeguards via managed access provisions.[34] Material transfers from disarmament could be in a sensitive shape or form. Similarly, fuel form, shape, cladding, and composition may reveal design specifications of a naval reactor core, which in turn may be relevant to the performance parameters of a nuclear-powered warship.[35] While the degree to which all states

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[32] Brazil, for example, has yet to sign the MAP and has argued that the Quadripartite Agreement, their safeguards system concluded in concert with Argentina and ABACC, represents an "alternative criterion." For more on Brazil's naval nuclear program, see Andrea de Sá, "Brazil's Nuclear Submarine Program," *Nonproliferation Review*, Vol. 22, No. 1 (2015), pp. 3–25.

[33] While details regarding fuel form, shape, and composition (including non-fissile materials) remain sensitive, Philippe argues that enrichment level "gives little indication of the actual tactical performance of the submarine propulsion system." Similarly, Feiveson suggests that enrichment levels "would not appear to reveal sensitive performance characteristics." Philippe, "Safeguarding the Military Naval Nuclear Fuel Cycle;" Harold A. Feiveson, "Treatment of Pre-existing Fissile Material Stocks in an FM(C)T," UNIDIR Resources, January 2010, <www.unidir.org/files/publications/pdfs/treatment-of-pre-existing-fissile-material-stocks-in-an-fm-c-t-392.pdf>; Chunyan Ma and Frank von Hippel, "Ending the Production of Highly Enriched Uranium for Naval Reactors," *Nonproliferation Review*, Vol. 8, No. 1 (2001), pp. 86–101.

[34] States' real and perceived national security concerns associated with material and processes in these stages may vary widely. We consider both information sensitivity and the feasibility of technical verification measures that protect confidential or classified information in regard to the viability of safeguards implementation.

[35] Clearly, there are potential challenges for naval safeguards with regard to information sensitivity and technical verification measures. The linkages between performance and fuel-design characteristics is exemplified by naval submarine maneuverability, which depends in part on the ability to vary the power of a naval reactor, which is in turn related to reactor design in terms of the capacity to control reactivity. Reactivity is a measure of the reactor's departure from a self-sustaining nuclear chain reaction, the phenomenon responsible for power generation in nuclear submarines. Reactivity margins are scoped to a certain degree by nuclear fuel design characteristics, because the fuel must be capable of withstanding the temperature swings resulting from power variation. Additional examples of the tie-ins

will agree to implement a safeguards system for fuel fabrication remains debatable, managed access techniques have been proposed for safeguarding fuel fabrication facilities that protect sensitive information and rely on well-established technical measures.[36]

Though back-end facilities for NNWS fall under safeguards through CSAs, information on naval nuclear power and performance may be gleaned from spent fuel assay and thus the back-end stages of the naval nuclear fuel cycle are designated as moderate-sensitivity installations. However, the need for information opacity in the interest of national security must be balanced against the risk of material diversion. Through an SP arrangement, technical safeguards measures in those naval fuel-cycle stages with moderate information sensitivity may be customized based on a state's specific fuel cycle (HEU/LEU), associated facilities, and nuclear-powered-submarine design characteristics to adequately balance information transparency and national-security concerns.

Once nuclear material is transferred to a naval base, the sensitivity of military information is high—as noted in green—and nuclear-material verification and safeguards are currently unlikely for states with item-specific agreements or VOAs. While diplomatic space for safeguards negotiations on moderate- and high-information sensitivity facilities may open through the technological advancement of remote sensing, attribute verification systems with information barriers, template-matching approaches, or physical cryptography, these technologies have not yet progressed to the level required for treaty verification.[37] As member states negotiate and design an SP for nuclear navies, leaving space for the inclusion and development of such approaches is vital to progress toward safeguards agreements that address and regulate venues of high military sensitivity.

Role of a Naval Nuclear Materials Committee

Having laid out the institutional strategy of an SP designed to safeguard naval nuclear material, we rely on lessons from the MAP process to propose the creation of a Naval Nuclear Materials Committee (NNMC) within the IAEA to negotiate a framework for an SP and provide a path for its development and implementation. The NNMC would necessarily include NWS, interested NNWS, and IAEA subject-matter experts to assess the technical parameters and political feasibility of the proposed SP. Moreover, we suggest that an NNMC is representative of the step-wise nature of the tiered SP system.

During the MAP process, IAEA Director General Hans Blix decided that safeguards measures required strengthening. He convened the IAEA Secretariat, Board, member

between nuclear-submarine performance and design characteristics are detailed in Jack Bell, Nathan Roskoff, Alireza Haghighat, and Joe Leidig, "Investigation into the Unintended Consequences of Converting the U.S. Nuclear Naval Fleet from Highly Enriched Uranium (HEU) to Low Enriched Uranium (LEU)," Virginia Tech Transport Theory Group, Arlington, VA, December 1, 2014, <https://fas.org/wp-content/uploads/2015/03/2015_VT_Converting_Naval_Fleet_from_HEU.pdf>; Nick Ritche, "The UK Naval Nuclear Propulsion Programme and Highly Enriched Uranium," FAS Task Force on Naval Nuclear Reactors, February 2015; Philippe, "Safeguarding the Military Naval Nuclear Fuel Cycle;" Feiveson, "Treatment of Pre-existing Fissile Material Stocks in an FMCT,".

36 Philippe, "Safeguarding the Military Naval Nuclear Fuel Cycle."

37 Jie Yan and Alexander Glaser, "Nuclear Warhead Verification: A Review of Attribute and Template Systems," *Science & Global Security*, Vol. 23, No. 3 (2015), pp. 157–70; Morten B., Maerli, "Timely Options for Increased Transparency and Non-intrusive Verification on Fresh Highly Enriched Uranium Naval Fuel," *Journal of Nuclear Materials Management* Vol. 31, No. 4 (2003), pp. 18–30; Alexander Glaser, Boaz Barak, and Robert Goldston, "A Zero-Knowledge Protocol for Nuclear Warhead Verification," *Nature*, Vol. 510, No. 7506 (2014), pp. 497–502; R. Scott Kemp, Areg Danagoulian, Ruaridh Macdonald, and Jayson Vavrek, "Physical Cryptographic Verification of Nuclear Warheads," *Proceedings of the National Academy of Sciences of the United States*, Vol. 113, No. 31 (2016), pp. 8,618–23.

states, and the Standing Advisory Group on Safeguards Implementation to negotiate the measures he laid out. The formal process for fortifying safeguards began in 1992, and in 1993 Programme 93 + 2 began. The Programme created proposal measures, regularly reported them to the Board, and used feedback from member states to adjust them.[38] It identified two types of strengthening measures: those which could already be implemented under existing legal authority (Part 1) and those which could benefit from additional legal authority (Part 2). Part 1 measures were, in effect, agreed to in 1995. In 1996, the Board established Committee 24 to negotiate a protocol based on the draft prepared by the Secretariat. The primary negotiations in Committee 24 were conducted between groups of countries including both NWS and NNWS which often disagreed on what measures they wanted the MAP to prioritize and address.[39] However, the states eventually were able to reach a consensus, by implementing the MAP based on their existing safeguards agreements. Upon agreement in the Committee, the draft MAP was submitted to the Board before it was approved in a special session on May 17, 1997.

The MAP process showcases the role of member states and IAEA institutional entrepreneurship as indispensable elements of strengthened nuclear-material safeguards. It also highlights the need for member states to serve at the helm of naval safeguards negotiations with IAEA support. Just as MAP negotiations proceeded through the Programme 93 + 2 and Committee 24 processes, the establishment of an NNMC within the IAEA to provide technical expertise and policy prescriptions is a first logical step to assess the framework for a naval nuclear SP.

The envisaged NNMC should convene all interested member states, in particular those with existing or planned naval nuclear programs—regardless of their existing safeguards agreements—and conduct an investigation into the scope of naval nuclear safeguards policies, including the types of facilities appropriate for coverage under an SP and any facility-specific rules and regulations. It is recommended that the NNMC consider facilities separately in the different tiers of information sensitivity outlined in Figure 1, as we expect states' views regarding the suitability of verification measures at each tier to vary. By examining these stages independently, step-wise progress may be made toward a universal protocol addressing national-security concerns associated with the naval base. Though safeguards policies focused solely on low-sensitivity facilities will limit an SP's potential effectiveness, they are an important first step in addressing naval nuclear stocks through a legally binding mechanism. Indeed, for HEU proliferation pathways, safeguards on enrichment facilities alone substantially decrease the proliferation risk. The incremental safeguarding of low-sensitivity facilities further opens diplomatic space for states to jointly consider safeguards in moderate- and high-sensitivity installations, whereby the limitations associated with military sensitivity, the opportunity for innovative technical measures such as adapted zero-knowledge verification mechanisms, and potential "managed access" provisions could also be explored.[40] Beyond opening a dialogue on

[38] Michael Rosenthal, Lisa Saum-Manning, Frank Houck, and George Anzelou, "Setting the Stage: 1991–1996," BNL-90962-2010, January 2010. See also S. van Moyland, *The IAEA's Programme "93+2"* (London, VERTIC: 1997).

[39] Frank Houck, Michael Rosenthal, and Norman Wulf, "Creation of the Model Additional Protocol," paper delivered at the Institute of Nuclear Materials Management 51st Annual Meeting, Baltimore, July 11–15, 2010.

[40] Sébastien Philippe, Robert Goldston, Alexander Glaser, and Francesco d'Errico, "A Physical Zero-Knowledge Object-Comparison System for Nuclear Warhead Verification," *Nature Communications*, Vol. 7 (2016), <www.nature.com/articles/ncomms12890>.

safeguards approaches in the naval nuclear sector, an additional benefit of an NNMC might be to foster exchange among naval-propulsion states on propulsion reactor safety.[41]

As mentioned, establishing an NNMC requires IAEA initiative, from either the director general or the member states. However, the current international climate does not lend itself to the independent promotion of such a matter by IAEA leadership. The Agency is persistently underfunded and faces increasing responsibilities, including monitoring and verification for Japan's Rokkasho reprocessing plant and responsibilities in international nuclear security which limit the political capital of the IAEA's director general and board.[42] The role of NWS in motivating and shepherding past safeguards instruments suggests one of them—the United States, United Kingdom, or France—as a logical candidate for leadership, akin to the United States' role in motivating discussions surrounding the Model Additional Protocol.[43] Beyond NWS, states such as Norway, Australia, and Canada—with strong commitments to nuclear nonproliferation—are also solid candidates for championing the safeguarding of naval nuclear stocks. Brazil, an NNWS actively pursuing a nuclear navy, would be an alternative guide and a potential advocate for this process, given the precedent-setting nature of any agreements this country will eventually make with the IAEA in designating its naval nuclear stocks.

Building on institutional strength

Another benefit of the SP approach is that its implementation would utilize the existing IAEA framework rather than start from scratch. Although the IAEA is not currently recognized as a technical authority on naval fuel issues, the step-wise, tiered SP process takes advantage of existing institutional knowledge pertaining to fuel-cycle processes in general terms as well as the IAEA's authority concerning safeguards. This places the IAEA in a central role in driving the regulatory standard-setting process forward. This approach leverages past developments in the safeguards regime to guide efforts that address new challenges, including the technical, legal, and economic details associated with safeguarding and verifying states' nuclear fuel-fabrication activities. Through this process, technical experts, in conjunction with member states, can identify the issues and scope of an SP that would be most palatable for all relevant states and determine the most appropriate measures to decrease the risks posed by naval nuclear materials.

Commitment plus tripwire

While the NPT's effectiveness in taking action toward uncooperative states is limited, as evidenced by past experiences with North Korea and Libya, state engagement through an SP could provide a formalized, legally binding obligation to safeguard naval nuclear materials.[44]

[41] Though there exists no historical precedent for international collaboration on naval nuclear-propulsion safety, NWS have demonstrated a willingness to cooperate on nuclear-weapons safety concerns and best practices. See, for example, Siegfried Hecker, *Doomed to Cooperate: How American and Russian Scientists Joined Forces to Avert Some of the Greatest Post-Cold War Nuclear Dangers* (Los Alamos, NM: Bathtub Row Press, 2016).

[42] Nuclear Threat Initiative (NTI), "IAEA Underfunding Risks Proliferation, Experts Say," November 30, 2010, <www.nti.org/gsn/article/iaea-underfunding-risks-proliferation-experts-say/>; Mark Goldberg, "The Cash-Strapped Agency at the Heart of the Iran Deal," *Atlantic*, July 18, 2015, <www.theatlantic.com/international/archive/2015/07/iaea-iran-nuclear-deal/398900/>; Statement by Mohamed ElBaradei, IAEA Director General, to the Fifty-First Regular Session of the IAEA General Conference, September 17, 2007.

[43] Susan F. Burk, "U.S.–IAEA Additional Protocol," Testimony Before the Senate Foreign Relations Committee, 108th Cong., 2nd sess., January 29, 2004, <https://2001-2009.state.gov/t/isn/rls/rm/29249.htm>.

Such an international commitment carries important normative implications through cooperation based on transparent and mutually agreed-upon standards. Though verification processes and technologies have limitations, the SP offers an early-warning mechanism for nuclear-material diversion toward weapons programs. The administrative procedures and technical verification measures also serve as a political tripwire to trigger additional monitoring or set in motion an international response via existing institutional frameworks.

Evolution of naval nuclear safeguards

While we note that states around the world have clear and accomplishable tasks to carry out vis-à-vis safeguarding naval nuclear material, recent developments in the theory and methods for nuclear-warhead verification offer synergistic promise for nuclear safeguards in the naval sector. The exemptions in the existing safeguards regime may be driven, in large part, by major powers' interest in exempting sensitive military technology from IAEA oversight. Nascent work on zero-knowledge systems and increasingly sophisticated remote-sensing tools are worth further consideration as part of new nuclear-material verification and safeguards efforts.

Proliferation risks are greatest where safeguards end. As the number of nuclear navies outside of existing international safeguards architecture expands, the threat of malicious actors acquiring and weaponizing fissile material increases. Given these risks, policy makers should proactively address the regulatory challenges posed by the development of nuclear navies, specifically, and the non-proscribed use of nuclear material, generally. A regulatory response, in the form of an SP, offers a comprehensive approach to addressing the risks posed by naval nuclear materials within the existing regulatory framework while taking into account the sensitivities associated with military technology.

The potential expansion of naval nuclear-propulsion programs threatens to rock the boat of the existing global nuclear-governance framework. Movement toward a safeguards regime for naval nuclear materials that engages all states—regardless of their nuclear-weapon status or existing safeguards obligations—is needed to foster critical preventative measures to ride out the brewing storm at sea.

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[44] George Perkovich, Jessica Mathews, Joseph Cirincione, Rose Gottemoeller, and Jon Wolfsthal, "Universal Compliance: A Strategy for Nuclear Security," Carnegie Endowment for International Peace, Washington, DC, March 2005, <www.nti.org/media/pdfs/analysis_carnegie_universalcompliance_2005.pdf>.