Advanced Nuclear and Emerging Technologies: Implications for Nuclear Safeguards and Export Controls

Recommendation Paper

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The Vienna Center for Disarmament and Non-Proliferation (VCDNP) convened three workshops between April 2019 and November 2020 with the support of the U.S. National Nuclear Security Administration (NNSA), to discuss the unique challenges and benefits that advanced and emerging technologies pose to nuclear safeguards and export controls.

The workshops brought together more than 50 individuals from nuclear supplier governments, industry, the International Atomic Energy Agency (IAEA) and think tanks. The workshops were held under the Chatham House Rule to encourage open and frank dialogue. This paper presents a set of recommended actions and initiatives which emerged from discussions and could be productive for the nuclear safeguards and export control communities.

The workshops focused on two categories of technologies:

- Nuclear and nuclear-related technologies that have not been comprehensively reviewed and addressed by any regime yet, such as advanced reactors, accident tolerant fuels, additive manufacturing and accelerators.

- Technologies that are not nuclear-related, but that have potential impacts on nuclear safeguards and export controls through their impact on business practices, such as cloud computing, artificial intelligence, encryption and distributed ledger technologies (DLT, of which blockchain is a subset).

Experts discussed the impact of nuclear fuel cycle concepts and evolving supply chain models on regulators and industry, as well as the impact of advanced manufacturing on export-import and localization. They also addressed the impact of emerging technologies on national, facility and company compliance. Some of the key takeaways from discussions include:

- The nuclear export control and safeguards communities have largely worked separately from each other, even though their non-proliferation objectives are mutually reinforcing and are derived from the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). A key takeaway from the workshops is that increasingly complex non-proliferation challenges call for regular dialogue and enhanced communication between the two communities in order to develop adequate responses and reach out to new stakeholders in a coherent way.

- Experts on these two sides of the regulatory landscape would benefit from partnering with industry and research and development institutions in an effective three-way dialogue, especially bearing in mind that many new start-up companies may not be familiar with

safeguards requirements and existing export controls on certain nuclear or nuclear-related dual-use items or may not be aware of the potential proliferation risks.

- From a regulatory point of view, the pace of innovation in the nuclear field is increasing dramatically and straining the ability of 70s-era regulatory structures to respond. Such innovations include new sources of financing, advanced designs, new manufacturing processes, and new ways to leverage data management solutions to facilitate global operations. Furthermore, globalized nuclear supply is driving companies to operate across borders and to localize and outsource manufacturing, which may create regulatory blind spots.

- Industry representatives highlighted challenges such as the difficulties of navigating multiple regulatory jurisdictions involved in a single transaction and understanding national and multilateral export control regulations.

- Industry also highlighted challenges associated with the lack of regulatory certainty around the use of emerging data management technologies and the wide variability in the guidance provided by governments on cloud-based storage of export-controlled data.

- The workshops also highlighted that regulators and industry often use different terms to describe the same concepts, and that this can be a barrier to effective communication. Developing regulatory guidance in a "common language" is therefore both a commercial and non-proliferation imperative.

- The workshops also identified the potential role of emerging technologies in supporting implementation of responsible policies, for example increasing compliance and verification or improving data management. Participants shared successful adoptions of advanced technologies such as artificial intelligence for the digitalization of export licensing processes and to simplify the analysis of end users and end uses for industry, as well as promising applications of DLT in securing the management of sensitive data in the nuclear fuel cycle.

The participants in the workshops expressed views on different areas where further work could be productive in the future. Some of them include:

1. **Develop strategies to increase awareness of safeguards-by-design (SBD) and promote its use**

SBD is a voluntary process and benefits all stakeholders when done as early as possible in the design process. It also saves resources by avoiding the need for designs to be retrofitted and by potentially facilitating export contracts. The workshop discussions underscored the need for awareness raising of SBD across industry.

A promising strategy discussed during the workshops is the adoption of a policy requirement at the national level for advanced reactor (AR) designers to demonstrate how safeguards considerations have been considered at the early stages of the design process. Enshrining SBD in a regulatory process is particularly useful.

At the national level, SBD can be promoted through early consultations between the national regulators and AR developers at the pre-conceptual and conceptual stages. Eventually, a trilateral dialogue between the national regulator, the designer and the IAEA will be important.

The role of third parties in promoting these early consultations is particularly relevant given their neutral capacity to allow for a "safe space'" for AR developers and regulators (national, regional and international) and also to assist regulators with socializing SBD within the AR industry. Awareness of SBD can also be promoted through participation by the IAEA and national authorities in relevant non-proliferation events, as well as fora related to the development of innovative nuclear reactors and fuels. It was also noted that the IAEA Director General's Standing Advisory Group on Safeguards Implementation (SAGSI) may play a useful role supporting efforts to promote SBD and its implementation.

For their part, new reactor designers can develop a strategy for consistent and active engagement, embrace the SBD concept and foster a strong safeguards culture. For them, SBD adoption may provide an additional marketing bonus.

2. Promote the adoption of a Code of Conduct for advanced manufacturing

Advanced manufacturing is one of the most significant emerging technologies discussed in the workshops, and it has potentially far-reaching implications across a variety of industries, including the nuclear industry. A code of conduct (CoC) for advanced manufacturing - especially for dedicated "print shops" that provide additive manufacturing (AM) as a service - could help address potential proliferation risks without stifling growth and innovation.

A CoC commits entities to an ethical behavior ("do-no-harm") and highlights *what* should be done or avoided. It is intended to be an effective way of raising awareness and, while it assists companies in complying with regulations, it intends to go beyond compliance by promoting ethical conduct of business for the greater good. It therefore does not replace regulations. A CoC also differs from standards, which are product-oriented. Standards relate to parameters and product quality and define *how* items should be made. In contrast, a CoC underpins voluntary self-restraint on the part of industry. The existing Nuclear Power Plant Exporters' Principles of Conduct is one prominent example of the use of CoC's in the nuclear industry.[1]

The promotion of a CoC likely would begin through engagement with a group of relevant companies, including established 3D printing service providers, to encourage ownership by industry. Working through industry associations could also be beneficial since many already have several CoCs. The engagement of industry should bear in mind the diversity of a field that includes start-ups, the do-it-yourself community and individual activities, targeting smaller companies in addition to industry leaders.

Arguments were raised both for limiting the CoC to AM in the nuclear field - in particular for new reactor technologies and innovative fuel designs - and for encouraging a more general approach that covers principles against proliferation of WMD as a whole.

Industry may find incentives to join a CoC given the expected reputational benefits that would lead customers to prefer products or services that come from a vendor that adheres to the CoC. Furthermore, adherence to a CoC could contribute to companies' public relations strategies

[1] https://carnegieendowment.org/publications/special/misc/nppe/

and business ethics programs, and could help avoid violations of export control and sanctions requirements.

3. Consider a potential update of Annex II of the IAEA Additional Protocol (AP)

The IAEA Model Additional Protocol (INFCIRC/540 as corrected) includes a requirement for States to provide the IAEA with a declaration containing information regarding exports of specified equipment and non-nuclear material listed in Annex II of the agreement. Discussions in the workshops highlighted the fact that this Annex has not been updated since its approval by the IAEA Board of Governors in 1997, raising questions about its ability to keep up with technological and commercial developments.

Any process to update the AP must be authorized by the IAEA Board of Governors. The formal start of such an effort will take place when the Board decides to establish an open-ended working Group of experts. However, an informal discussion between nuclear safeguards and export control experts could provide possible input to a future update process by identifying what items could to be added to Annex II of the AP, as well as the rationales for such additions. In developing this exercise, experts could look at several recently updated reference documents in the fields of safeguards and export controls.

4. Conduct research on the evolving business practices used by developers of advanced nuclear technologies

The workshops shed light on the dynamic evolution of nuclear technology and the nuclear field. Historically, nuclear research and development has been primarily funded and directed by governments. Increasingly, non-traditional investors are funding and looking for ways to revolutionize the nuclear industry, and many advanced reactor and fuel concepts are based on non-traditional supply models, such as use of private financing or venture capital. The development sphere now includes several start-ups and an increasing number of new private companies, which provides a clear indicator that a global and diversified supply chain is the norm for the nuclear industry.

It was suggested that governmental authorities and regimes must take stock of these new technologies and processes for potential export control and safeguards implications. Experts highlighted the importance of conducting further research with an emphasis on the evolving business strategies and practices associated with innovative nuclear technologies, in order to better understand who is doing what, the networks and their interrelationship, and to further assess their implications for nuclear safeguards and export controls.

5. Conduct joint outreach to promote responsible and integrated approaches in the nuclear fuel cycle: “non-proliferation by design”

The dynamic changes in the nuclear field also mean that new nuclear vendors and manufacturers will need to be educated on the fundamentals of the nuclear non-proliferation regime, including safeguards requirements, national export control regulations, and global non-proliferation norms. In order to effectively engage with new entrants into the nuclear industry, regulators should cast a wide net in their outreach activities to ensure that industry is well-informed of their non-proliferation responsibilities.

Awareness raising and outreach to industry requires targeted and tailored approaches to address the specific needs of industry in complying with the different requirements of export controls and safeguards regulations. However, the workshops also highlighted the benefits that could arise from an additional integrated awareness-raising approach to outreach. An integrated narrative that encompasses export controls, safeguards, and other obligations and requirements, and that speaks a common language and highlights several benefits of compliance could yield significant benefits in raising awareness among the targeted industries and communities. In this regard, language becomes extremely relevant, as the dry and complex wording of regulations needs to be "translated" for newcomers to highlight the "bigger picture" of the principles underpinning responsible behavior in the nuclear field.

Discussions showed that reaching out to developers in a comprehensive way could not only raise the importance of the "3-S approach" (safeguards, nuclear security and nuclear safety) but also incorporate elements of export controls in what could be called "non-proliferation by design". This concept could help bridge differences among the various communities. In this regard, conversations around building narratives and developing common culture were strongly supported as ways to highlight the advantages for all derived from compliance.

Suitable outreach opportunities to jointly promote responsible policies in the nuclear field could include the following strategies:

- Promote regulatory outreach activities tailored for nuclear industry and researchers that integrate export control, safeguards, security, and other nonproliferation considerations. Such outreach could take the form of new, dedicated meetings or presentations at existing conferences and other events.
- Raise awareness through funding mechanisms – both government funding agencies and private financial institutions could establish eligibility criteria related to strengthening regulatory compliance; and
- Major companies in the nuclear field could promote responsible policies and compliance within their supply chain and share the integrated narrative with their smaller second and third tier suppliers. Some of these large companies may already have a CoC for suppliers.

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Finally, there was strong consensus amongst participants that a stronger, sustained and informal dialogue between the nuclear safeguards and export control communities could be highly beneficial to support responsible policies in the nuclear field, to promote ideas to be further used by stakeholders, and to identify good practices in the adoption of emerging technologies.

The workshops highlighted that the nuclear export control and safeguards communities have largely worked separately from each other and that stronger dialogue between the two communities could help better address non-proliferation challenges. If kept informal and convened by a neutral third party, this dialogue could permit experts from both communities to interact in a fruitful way and to address additional areas of overlap between both communities.