Developing A Security Program for The X-Energy HALEU Fuel Fabrication Facility To Support Advanced Reactors

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Abstract

As applicants and vendors begin to bring their concepts for advanced reactors and associated fuel fabrication facilities to fruition, regulatory uncertainty presents significant challenges. This paper provides a historical discussion of NRC regulatory activities related to the security of HALEU. The protection of high assay LEU (HALEU) which is used in most advanced reactor fuels is covered by regulations more than four decades old. Although a rulemaking was begun, it was recently canceled. Security is expected to be regulated on a case-by-case basis. This results in uncertainty and introduces regulatory risk for the commissioning of HALEU fuel fabrication facilities. This paper provides a historical summary of NRC's development of a technical approach for security of HALEU and provides a summary of the approach under development by X-Energy for providing security for its HALEU fuel fabrication facility.

Background

As applicants and vendors begin to bring their concepts for advanced reactors and associated fuel fabrication facilities to fruition, regulatory uncertainty presents significant challenges. The current Nuclear Regulatory Commission (NRC) regulations that are detailed in 10 CFR73.67 were put into place in 1979. These regulations were a significant improvement over previous regulations, but do not identify appropriate or adequate security for high-assay low enriched uranium (HALEU) that would be necessary today. When the current regulations were drafted, little or no consideration was given to the protection of large quantities of HALEU. The focus at the time was how to protect high enriched uranium. Since 1979, our understanding of the threat has evolved and with the movement toward advanced reactors, there will likely be many facilities that possess large quantities of HALEU.

In 2008, the NRC staff began development of the Enhanced Security of Special Nuclear Material (SNM) Rulemaking. This rulemaking focused on the development of requirements for the protection of SNM that were related to the attractiveness of the SNM to a potential adversary. It was expected to make NRC security regulations more consistent with DOE security requirements yet remain compatible with international guidelines. The rulemaking included a substantial amount of technical analysis supported by Los Alamos National Laboratory, as well as both domestic and international stakeholders. A regulatory basis was published in 2015 and the development of rule language began. However, the rulemaking was stopped in 2018, due to budget reasons. As a result, the staff told the Commission that they would determine security requirements for Category II HALEU facilities, considering the technical approach from the rulemaking, on a case-by-case basis. With no regulations or guidance for this technical approach, there is a lot of uncertainty as to what the appropriate security should be for these facilities and what will be required to obtain a license from the NRC.

Considerations

The security to protect against theft and diversion for HALEU facilities will be substantially different than the security approaches that are in place at high enriched uranium (HEU) and plutonium facilities. At those facilities, theft targets could be as small as a hockey puck, when considering a plutonium metal button, or a small can of oxide. Target quantities at HEU and plutonium facilities are usually established as Category I quantities. However, there is no Category I quantity for HALEU. Since no quantity of HALEU can result in a Category I quantity of SNM, a goal or target quantity for Category II HALEU needs to be developed to establish an appropriate goal for protection against theft. For plutonium, the Category I threshold is four times the Category II threshold, and for high-enriched uranium (HEU) it is a factor of five over the Category II threshold. To be conservative, using a four times factor would be appropriate. The Category II threshold for HALEU is 10 kg U-235. Therefore, the goal quantity that could be used is 40 kg U-235. Given this target quantity, the target quantities that would be used in theft analysis for a HALEU fuel fabrication facility would be very large quantities of mass and volume. For example, uranium feedstock comprised of oxide would require hundreds of kilograms to achieve a target quantity. The finished product would typically require multiple tons of material.

Another difference between protection strategies of Category I facilities and HALEU facilities is the possibility of relying on armed response from local law enforcement agencies (LLEAs) rather than having an onsite response force. However, to accomplish this, it is necessary to establish sufficient delay with early detection to allow the LLEA response force to arrive in time to interdict the adversary prior to departure from the site. There is no clear guidance on what the timing should be. As such, it is important to derive a graded approach to the level of confidence that LLEA would arrive sufficiently early. There are two cases. The first case is where a facility has a Category II quantity of HALEU, but not a goal/target quantity. In this case, it would seem appropriate to have moderate confidence that LLEA would arrive on time. However, if a facility has a goal/target quantity of HALEU, it would be more appropriate to have high confidence. It would seem reasonable that if there is sufficient delay to extend the adversary task time to greater than or equal to 110% of the negotiated and validated median response time for LLEA to the site. To achieve high confidence, it would be necessary for the adversary task time to be greater than or equal to 150% of the negotiated and validated LLEA response time to the site.

Additionally, there are a number of things that will need to be available to the adversary to accomplish the objective of theft of a goal quantity of HALEU:

- Given the large volume of material, the adversary will acquire material that is containerized,
- Given the large volume of material, the adversary will require one or more vans, box trucks, or tractor trailers,
- The adversary will need access to plant forklifts, palette movers, or carts, or bring its own carts, and
- Cordless hand tools to open or breach delay features.

Also, there is a need for layered protection and defense-in-depth. Layered protection can be accomplished by having concentric zones around the material. For example, the layers could include site perimeter fencing, controlled access area (CAA) boundaries, and specific delay features close to the material. Defense-in-depth measures should be independent measures that will compensate for potential failures in the security program.

Security/Delay Features to be Considered

Cameras should be deployed in appropriate locations to allow assessment, as well of awareness as to the location of the adversary on the site.

At the site boundary, some form of fencing with vehicle barriers and sensing should be deployed to achieve early detection and make the adversary's introduction of a vehicle to transport the stolen material more challenging. In many cases, chain link fencing would be sufficient. It would need to be complemented with some form of vehicle barriers, such as trees, vehicle/aircraft cables, concrete blocks, large rocks, or terrain features. This approach forces the adversary to attempt access at established vehicle portals that would lkikely have vehicle barrier systems and sensors or observation by security staff. This would provide high assurance that detection would be achieved when the adversary crosses the site boundary.

Given the large volume and mass of the material that will be targeted, it is highly probable that the adversary will use an access point to the CAA to remove the acquired material. Otherwise, additional time will be required to pick up and carry the material through the boundary. As such the security features should be focused on access points to the CAA. Given the weight of the vehicles and load to be carried, the adversary will likely attempt to use existing loading areas, less likely to use emergency exits or personnel access points. Given these considerations, it may not be necessary to alarm the entire exterior surface of the CAA, but instead rely on the use of random patrols. However, access points should be alarmed and sealed. Some form of fencing should be in place at loading areas to form exclusion areas to preclude the adversary 's ability to place its transport vehicles adjacent to the CAA.

The next consideration is how to achieve delay in proximity to the HALEU's storage location. For HALEU that is within the process area, and is a credible theft target, it is important to install some form of delay features, such as steel cages, steel lock bars, steel mesh cages. The number of individual cages/bars may be determined by the amount of delay required.

More attractive material, such as oxide feedstock, would generally be stored in a vault type room (VTR). The VTR should have walls from the floor to ceiling. The exterior surface should provide indication of breaching by an adversary. The VTR should have sensors to provide intrusion detection, possibly including volumetric sensors. Cameras should be installed for assessment. To afford delay, material should be retained in shipping containers, if they are heavy and/or require significant time/special tools to access the HALEU inside. Retaining them in shipping containers may force the adversary to remove cans from within to reduce the mass of the material to be removed from the facility, allowing for more delay. These containers could be stored within steel cages or steel mesh cages to increase delay time. Another consideration is the potential use of activated features, such as turning off power, or the introduction of obscurants or slippery agents to the VTR.

The previous measures have focused on challenging or delaying the adversary's access to the material or the acquisition of the material. Next, it is important to add delay or challenge the adversary's ability to transport the material to its vehicle. Then first option would be to remove forklifts, palette movers, and carts from proximity to the material, either to add delay time for adversary to acquire this equipment or to preclude its use. This may force the adversary to bring carts for material movement. Next, it is important to put into place barriers to preclude continuous movement of material on carts or other transport devices. This might include steel barriers that can be locked, raised and lowered. It may also be achieved through the use of steel cabling. If these impediments are in place, the adversary will be required to offload the material from the cart, hand carry it over the barrier and reload the cart. This adds additional delay each time one of these barriers is encountered.

Finally, it is important to consider putting measures into place that would preclude the HALEU from being transported offsite in the event that it was able to acquire the material and load it into the transport vehicles. The most reasonable approach would be to deflate the tires of the transport vehicles. It is quite difficult to rapidly transport tons of material with deflated tires.

Adversary Task Time

It is first necessary to determine the number of adversaries that will be involved in the attempt to rmove the HALEU from the facility. Next, it is important to identify which combinations of items are necessary to acquire a goal quantity. Next, it is necessary to calculate the transit times and task times to acquire the HALEU. These should incorporate delay times associated with the delay features that are required to be overcome. The total adversary task time should be calculated from the time of first detection to the time of departure from the site.

The security program needs to include early detection to enable sufficient delay. Hence, for a facility with more than a goal quantity of HALEU, the security system should be designed such that the adversary requires more than 150% of the negotiated and validated response time for LLEA response. It should also provide defense-in-depth measures to compensate for any failures in delay or security measures.

Conclusion

Each HALEU facility is unique, so the measures that are selected for security and delay are likely to be different for each of them. Currently, there are three HALEU facilities under design, construction or operation that will utilize different features. The facilities include a medical isotope facility, en enrichment facility, and a fuel fabrication facility. In addition, if sufficient delay cannot be incorporated into the security program to allow for timely LLEA response, it may be necessary for the site to have its own armed response force.