White Paper On

The Development of Process Models for Clandestine Proliferation

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1.0 Problem definition

Undeclared nuclear activities are, by definition, processes spanning long periods of time. Depending on the level of technical and scientific expertise available in the proliferating State as well as the level of effort, these processes may involve multiple paths some of which may lead to dead ends.

From the perspective of the IAEA, the objective is to develop procedures for detecting the existence of such processes. The framework for developing such procedures is the Additional Protocol that requires evaluation of the State as a whole on the basis of the information submitted by the State and any additional information collected by the IAEA during inspections. The challenge for the IAEA is how to develop an evaluation methodology that is objective and transparent, yet, does "not mechanistically or systematically seek to verify the information", whatever these particular words might mean, nor does it rely on "detailed nuclear material accountancy" to verify declarations [Cooley].

One avenue of investigation is using the concept of critical path analysis that seeks to identify for each State all possible clandestine paths on the basis of existing declared nuclear activities. These activities can range from none to advanced stages of the nuclear cycle such as enrichment and reprocessing. Under this concept, when a State decides to start a clandestine nuclear weapon development program, it will build upon the existing scientific and technological expertise. In this case, the challenge is how to construct a mechanism for detecting undeclared activities while verifying the declarations by the State.

A State with declared multiple stages of the fuel cycle, has the option of initiating a clandestine program at any of those stages. The choice of what can be referred to as the "break off" stage may depend on many factors, one of them being the stage with the smallest probability of detection. Under the concept of critical path analysis, the IAEA examines all critical paths and formulates a safeguards approach mainly on the basis of expert judgment. By its nature, expert judgment is subjective and can be used, or be perceived as being used, in a discriminatory manner among the States. One formal procedure proposed for improving the application of expert judgment involves the evaluation of all critical paths on the basis of the attractiveness of each such path to the State as determined by factors such as technical difficulty, proliferation time and proliferation cost [Listner]. Using game-theoretic concepts, optimal strategies are developed by deciding which of the many possible paths us optimal for the State. These strategies are based on the assumption that the Additional Protocol will provide a high probability of detection compared with that offered by traditional safeguards. To our knowledge there is no rigorous analysis relating the detection probability for a given acquisition path to the data collected under the Additional Protocol. Furthermore, the dearth of experience in detecting clandestine proliferation raising questions about the reliability of such expert judgments.

2.0 The need for a process model

A clandestine nuclear weapons program is a multi-path and multi-step process. Although the nuclear material is the critical components, there need to be concurrent development programs in electronics, fabrication and testing for the program to succeed. One can visualize a scenario whereby a State develops a clandestine capability for assembling and testing all components of a nuclear device without engaging in clandestine operations involving nuclear material. For example, one path would lead to the acquisition of acquisition of highly accurate timing circuitry, yet another to the acquisition of capabilities for precision tooling. In the present context, the term acquisition denotes capability either developed indigenously or imported. Even the acquisition of the nuclear material involves multiple paths and multiple steps. There are more options than the widely used gas centrifuge method for enriching uranium each requiring different technologies. In addition, enrichment is done in stages, each involving varying degrees of effort.

The starting points of a clandestine weapons program are unique to each State. For example, in a State with indigenous advanced electronics manufacturing, the capability to acquire the trigger mechanism would already be present in the form of advanced circuitry and engineering personnel. On the other hand, the same path for a State with non-existent or minimal electronics manufacturing capabilities would consist of many steps until the attainment of the capability to manufacture a working trigger mechanism. Similar reasoning applies to the paths for the clandestine acquisition of highly enriched uranium or plutonium. Thus, although the various acquisition paths have been well documented, their internal structure, namely, how many steps each of those paths contain, is not well-defined and it is correlated with the technological capabilities of each State. Regardless how each of the paths starts, the development of the relevant technologies is a discrete step process. Each step involves, *inter alia*, planning, design, experimentation, testing, and verification of design prior to the next step of development.

The foregoing illustrates that a nuclear weapons development program is dynamic process with variables changing over time and in secret. The criterion of objectivity requires that the probability of detection of possible clandestine proliferation activities be calculated from the data (measurements) collected under the Additional Protocol. These measurements are very noisy, particularly those pertaining to nuclear materials, because they cannot be verified through material accountancy. In turn, the measurements must be sufficient (quantity and quality) to identify any of the many possible clandestine processes. To do so, there is a need to relate parameters of all such processes to the information available to the IAEA. Since a clandestine program most likely would involve many trial-and-error approaches as well as dead-ends, the process parameters are, by necessity, stochastic rather than deterministic. In conclusion, the focus of the discussion needs to be on the development of algorithms that detect activities in processes that are not clearly defined using very noisy data in order to implement an objective and effective safeguards regime on the State as a whole. Developing process models for all possible diversion paths would be a major challenge that could be addresses by establishing criteria for prioritization by identifying and taking into account condition specific to each State.