IMPROVING IAEA SAFEGUARDS THROUGH ENHANCED INFORMATION ANALYSIS

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As a part of its efforts to strengthen international safeguards, including enhancing its ability to detect any undeclared nuclear activities, the International Atomic Energy Agency (IAEA) is using increased amounts and types of information on states' nuclear and nuclear-related activities. This information includes information provided by states (e.g., expanded declarations), information collected by the Agency (e.g., environmental monitoring data), and other information available to the Agency (e.g., media information). Part of "Programme 93+2," the Agency's effort to increase the effectiveness of international safeguards, involves the development of a comprehensive approach to the acquisition, management, and analysis of this diverse information. The general approach is to compare a *state's declared nuclear activities* with *supplementary information available to the Agency* and to look into any apparent inconsistencies. Because of the size and growth of the information, tools are being developed to facilitate this comparative analysis, including a computerized system that allows an analyst to view a state's entire nuclear program and any evidence of undeclared nuclear activities. This article describes the concept of the information analysis system and the status of tool development.[1]

GENERAL APPROACH

Task 5 of the IAEA's Programme 93+2 focuses on the acquisition, management, and analysis of the increasing amount and types of information available to the Agency about a state's nuclear-related activities. The result should be an information analysis system that efficiently uses Secretariat resources to identify at an early stage any apparent inconsistency between the available information about a state's nuclear activities and the state's declaration. The approach being taken involves the development of several tools to be used by a dedicated team of analysts.[2]

The information being acquired, managed, and analyzed includes 1) expanded declarations, 2) design information, 3) reports on imports/exports of nuclear material and specified equipment and non-nuclear material, 4) safeguards inspection data, including results from strengthening measures such as environmental monitoring, 5) open source information such as general media reporting, trade press, and IAEA open databases, and 6) information made available from member states. Also under consideration is commercial satellite imagery.

Figure 1 displays the approach graphically. The Agency has access to two types of information about a state's nuclear-related activities: information supplied by the state and information from sources indepen-

Figure 1. General Approach

dent of the state. The former category is depicted on the left side of Figure 1, which constitutes the state's declared nuclear-related activities. The latter category is depicted on the right side, representing the Agency's supplementary information on the state's nuclear-related activities.

The general approach is to compare these two types of information both internally and with each other. For example, an internal "consistency check" of state-supplied information could include evaluating whether a state's declared imports of nuclear material are generally consistent with its declared nuclear facilities. An internal consistency check can also be used to assess the reliability of information.

The next (and primary) step shown in Figure 1 is to compare the *Agency's supplementary information* with the *state's declaration*. For example, environmental monitoring results can be compared to the state's declared nuclear activities to provide evidence of the absence of undeclared activities or evidence of the possibility that such activities may exist. Another example is to compare reports of imports with the nuclear activities a state has declared. An import of an item that is only used in a nuclear activity not declared by the state would be an inconsistency. In general, if an inconsistency between state-supplied and Agency supplementary information were found, the matter would be examined more closely to see if an information source is simply inaccurate. If the matter were still not resolved, further investigation could be required.

Because of the size and growth of the information being utilized by the Agency, it is beneficial to develop tools to assist analysts in going through the process described above. Task 5 has therefore pursued various ways to manage, display, and help analysts evaluate information on states' nuclear activities. Under development is a computerized system that allows the analyst to view a state's entire nuclear program in a coherent and connected way. The analyst can then explore individual activities at increasing levels of detail. For instance, an analyst could view on a computer screen (see schematic in Figure 2) a general overview of a state's declared nuclear activities and any existing evidence of undeclared activities, including misuse of declared facilities. The example in Figure 2 shows an arrow on the enrichment block, indicating that evidence of undeclared enrichment activity exists in the state

Figure 2. Top-Level Computer Screen

being analyzed. Shaded blocks mean the state has declared those activities.

By clicking on a specific nuclear activity (e.g., enrichment), more detailed information is displayed. This includes the following generic (i.e., non-country and non-facility specific) information:

- information about how that nuclear activity or process works;
- a list of indicators of that nuclear activity, including equipment, materials, technology, effluents, and other observables;
- the strength of each indicator, as determined by the degree to which it is associated with nuclear as opposed to other activities, i.e., the more specific the indicator is to the nuclear activity, the stronger the indicator. (For equipment and materials, this is often expressed as whether an item is "especially designed" for nuclear use, or "dual-use."); and
- a description of each indicator.

In addition, the following country-specific information can be displayed by clicking on a specific nuclear activity:

- notations on the existence of any declared activities;
- a list of any existing evidence of undeclared nuclear activity, the strength of that evidence, and references to information sources;
- graphical information such as facility line drawings and design information; and
- maps showing locations of nuclear activities and environmental monitoring results.

The system is envisioned as being useful not only to analysts, but also to inspectors to prepare them for what they should see or look for during a particular inspection.

Key elements of the information analysis system include 1) a wide range of information sources, 2) a structure referred to as the Proliferation Critical Path, 3) a detailed physical model that describes nuclear processes, including indicators of each process, 4) logical "if-then" rules that identify information as evidence of a particular nuclear activity, and 5) a set of computer tools that enables the efficient management and processing of information. At the heart of this information analysis system is a team of analysts and inspectors.

PROLIFERATION CRITICAL PATH

With expert assistance from member states, a Proliferation Critical Path has been developed to provide a systematic means of categorizing and recording relevant information from the various sources to enable the effective and efficient analysis of the data. The resultant structure generally follows the steps that would be involved in the nuclear fuel cycle from source material acquisition to the production of weapons-usable material, and then beyond the fuel cycle to weaponization.

The Proliferation Critical Path is designed to include all known pathways for the production of weapons-usable material and subsequent weaponization. The Path's top level contains all the main activities that may be involved in proliferation (see Figure 2). Each activity in the top level is broken down into more specific routes or processes. For example, enrichment is broken down into nine possible enrichment processes (gas centrifuge, electromagnetic, aerodynamic, gaseous diffusion, molecular laser, atomic vapor laser, plasma separation, chemical exchange, and ion exchange).

PHYSICAL MODEL

The Physical Model contains detailed narratives and illustrations describing each nuclear activity represented at all levels of the Proliferation Critical Path. It identifies and describes *indicators* of the existence or development of the activity, such as specialized equipment, dual-use equipment, nuclear and non-nuclear materials, technology, and environmental signatures. As an example, some of the indicators related to gaseous diffusion enrichment are illustrated in Figure 3.

Figure 3. Sample Indicators of Gaseous Diffusion Enrichment

Equipment Indicators
- -gaseous diffusion barriers
- -gas blowers

Material Indicators
- -uranium hexafluoride
- -chlorine trifluoride

Environmental Monitoring Indicators
- -hydrogen fluoride or fluorinated compounds derived from uranium hexafluoride
- -evidence of perturbed uranium isotopics

Other Indicators
- -large heat increases in air or water
- -large amounts of power going into a large facility

Compilations of many types of nuclear-related equipment and materials already exist in the form of guidelines for nuclear exports. One such list is that reproduced in INFCIRC/254, which was a helpful resource in writing the Physical Model.

Nuclear experts from member states identified additional items, by-products, and other observables that are indicators of the nuclear activities represented in the Proliferation Critical Path. These consultants also assisted Agency staff in determining the specificity of each indicator to a given nuclear activity. The specificity is used to determine the *strength* of an indicator. An indicator that is present only if the nuclear activity exists or is under development is a strong indicator. Conversely, an indicator, such as a piece of equipment, that has many other end uses is a weak indicator. In between are medium indicators.

The Physical Model is meant to be used by Agency analysts to better evaluate the nuclear-related significance of information on a state's activities. For example, when evaluating information on a state's imports, the Physical Model helps the analyst determine if an import may be useful in a nuclear activity not declared by that state. The Physical Model may also be used by safeguards inspectors to help them know what to look for, i.e., indicators of undeclared nuclear activities or misuse of declared facilities. If there are sufficient indicators of an undeclared activity in a state, the Agency can direct its attention toward clarifying the actual situation.

LOGICAL IF-THEN RULES

The relationship between an indicator and a specific nuclear activity is called a "rule." Given a particular indicator and its strength, a rule lets one infer the possible presence of an activity (or lack thereof). Assume one is interested in assurance that an undeclared activity ***A*** is not taking place. The Physical Model describes the characteristics of the activity, including the material, equipment, and technologies required to undertake it, as well as effluents that may serve as environmental signatures. Assume a strong indicator of this activity is equipment ***Q***, which experts agree is necessarily present if activity ***A*** is undertaken. The rule would read:

IF <material ***Q*** exists>,
THEN <associate the equipment ***Q*** with the possibility of activity ***A***>.

For example, the Physical Model identifies rotary assembly equipment as being dual-use (that is, usable for non-nuclear purposes), but often used to produce rotors for gas centrifuges. Rotary assembly equipment is therefore categorized as a medium indicator of gas centrifuge enrichment, resulting in the rule, "*If* rotary assembly equipment exists in a state, *then* there is medium evidence that gas centrifuge enrichment exists or is under development."

These rules help match input information with associated nuclear activities. In the example above, rotary assembly equipment is associated with gas centrifuge enrichment. If evidence of undeclared activity accumulates, an analyst can investigate further. More complex rules can also be formulated, such as, "*If* there is medium evidence that a state is producing UF_6 *and* has no reactors *and* does not export UF_6, *then* an analyst should investigate whether the state is in fact producing UF_6 and, if so, why."

RULE-BASED SYSTEM

The quantity of logical "if-then" rules being developed is becoming large. The large number of rules, the complex interrelationships between them, and the increasing volume of input data make computerization very attractive. Consequently, a computerized Rule-Based System (a type of expert system) is being developed that contains the rules. This Rule-Based System, referred to as VENAS (Visualization of Evidence on Nuclear Activities of States), is a key component of the computerized system described in the General Approach section of this article. VENAS is based on the commercially available software NEXPERT™.

The hundreds of rules developed from the Physical Model are placed in VENAS, which operates on input information by identifying and categorizing significant information according to its associated nuclear activity. VENAS provides the analyst a compilation of existing indicators (i.e., evidence) and their strengths for any undeclared nuclear activities in a state. It also recognizes combinations of indicators that are especially strong evidence of a particular nuclear activity.

The operation of VENAS begins with declared information and incrementally builds evidence of any possible undeclared nuclear activities from input information about indicators existing in a given state. The results are displayed in the structure of the Proliferation Critical Path, with any potentially undeclared activities increasingly highlighted as the amount and strength of associated evidence increases. The analyst can see a complete overview of all activities in the Proliferation Critical Path (see Figure 2), with details available on demand by clicking on the block of interest.

OPEN SOURCE INFORMATION

Current Agency databases on nuclear fuel cycle facilities and power and research reactors have been identified as useful information sources to complement the safeguards confidential sources.

Nuclear topics in general, and especially those relating to proliferation or potentially controversial transfer of technology, now receive wide coverage by the media. Nonproliferation centers of study in such organizations as the Carnegie Foundation and Monterey Institute of International Studies also give the subject prominence. Articles appearing in newspapers as well as nuclear, general scientific, and defense-related periodicals and topical papers from the research institutes can contribute usefully to the Agency's knowledge base.

The following are some of the available media and other public sources currently reviewed on a regular basis:

- The **Daily Press Review** (DPR): This is the "newsclip" service of the Agency. It is published every workday and contains articles from about 91 newspapers and journals.
- **Carnegie Institute Nuclear Non-Proliferation Network** (NNN): Through the Internet, the Agency receives wire service articles and comments on nuclear issues daily from the Carnegie Institute.
- **Joint Publications Research Service** (JPRS): This is a hardcopy document published biweekly from worldwide coverage of the news media.
- **Emerging Nuclear Suppliers Database** of the Monterey Institute of International Studies: This provides abstracts of articles from a wide variety of publications worldwide. Its principal attributes are the selection and summarizing that are performed prior to receipt by the Agency. It is updated monthly.
- **Specialist nuclear periodicals**: *Nuclear Engineering International* and *Nucleonics Week* are separately scanned in case of omissions from DPR.
- **Defense-related periodicals** such as *Jane's Defence Weekly, Jane's Intelligence Review, Jane's Defence Contracts*, and the Arms Control Association's monthly *Arms Control Today*, produce occasional, valuable, nuclear-related articles.

Data from these sources are in the process of being input to a database that utilizes the commercially available software TOPIC™, which utilizes sets of keywords to search and select data of interest. Indicators of nuclear activities, as defined by the Physical Model, are included in the list of keywords.

Also under consideration is the Kurchatov Institute nonproliferation and fuel cycle database, as well as nonproliferation reviews published in member states. Commercial satellite imagery is another potentially valuable source of information that is currently being investigated.

The sharing of export licensing data on a confidential basis by member states, particularly those license applications denied because of proliferation concerns, would be a valuable addition to the information analysis system and would not require significant effort to incorporate.

STATUS

The current status of development of the information analysis system is summarized as follows:

- **Physical Model**—Descriptions of all nuclear activities at all levels of the Proliferation Critical Path have been drafted.
- **If-Then Rules**—Indicators from the Physical Model have been incorporated into rules for all nuclear activities.
- **Computerized Rule-Based System**—Rules and information on declared activities are being input to VENAS.
- **Open-Source Database**—A prototype has been developed and is operating.
- **Other Computer Tools**—Watson, developed by Lawrence Livermore National Laboratories, is being developed and tested as a presentation tool of textual, geographic, and image data. A geographic information system is also being investigated for storing and managing environmental monitoring data.

The information analysis system is expected to be in routine use at the IAEA in 1996. The system is anticipated to bring the detection of *undeclared* nuclear activities under systematic and orderly analysis, like the IAEA routinely operates for the detection of diversions in *declared* activities. It also provides an additional tool for monitoring such declared activities.

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[1] Many people have contributed to the improvement of the Agency's information analysis capabilities, including several Agency staff members as well as consultants from France, Australia, the United Kingdom, and the United States. Assistance has also been provided through Member State Support Program projects.

[2] J. L. King, "Improved Analysis of Information on States' Nuclear Activities," presented at the 35th Annual Meeting of the INMM held in Naples, Florida, July 1994.